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Report No. CG-D-19-90

AD-A231 004

SIDE-BY-SIDE SEAKEEPING AND POWER PLANT COMPARISONS OF THE SURFACE EFFECT SHIPS (SES) USCGC SEA HAWK AND USN SES-200

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FINAL REPORT
JUNE 1990

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Prepared for:

U.S. Department Of Transportation
United States Coast Guard
Office of Engineering, Logistics. and Development
Washington, DC 20593-0001

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CG-D-19-90		

4. Title and Subtitle	5. Report Date
Side-by-Side Seakeeping and Power Plant Comparisons of the Surface Effect Ships (SES) USCGC SEA HAWK and USN SES-200	June 1990
	6. Performing Organization Code
7. Author(s) Thomas Coe	8. Performing Organization Report No. R&DC 06/90
9. Performing Organization Name and Address United States Coast Guard Research and Development Center Avery Point Groton, CT 06340-6096	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Department of Transportation U.S. Coast Guard Office of Engineering, Logistics and Development, Washington, D.C. 20593-0001	13. Type of Report and Period Covered Final 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The performance characteristics of the U.S. Coast Guard 110' Surface Effect Ship (SES) CGC SEA HAWK and 160' U.S. Navy SES-200 are documented and compared. Engine performance in calm water and side-by-side rough water seakeeping performance tests were conducted in the Atlantic Ocean south of Key West, Florida. The SES-200 ride control system was evaluated in the seaway. The NASA Ride Quality Meter and Bruel and Kjaer Human Response Vibration Meter are compared and were utilized to document the discomfort level and human fatigue on board the SEA HAWK.

17. Key Words	18. Distribution Statement
Surface Effect Ship, SES, SES-200, Side-by-Side, Technical Evaluation, Seakeeping, USCGC SEA HAWK, Ride Control System	Document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. SECURITY CLASSIF. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

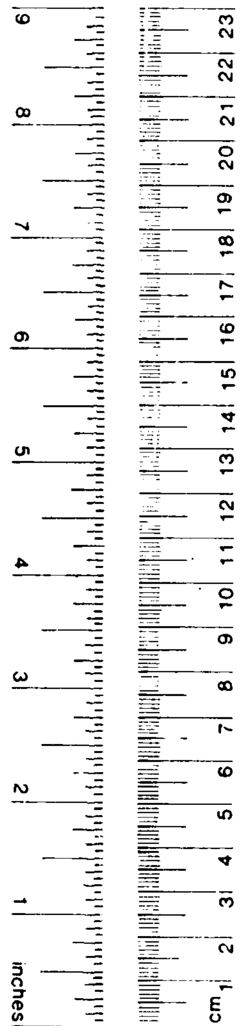
Form DOT F 1700.7 (8/72) Reproduction of form and completed page is authorized.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

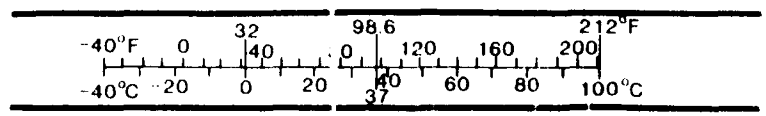
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

The U.S. Coast Guard Office of Research and Development is in the process of evaluating advanced surface craft concepts as well as documenting the performance of present cutters to support the vessel aquisition process. The Coast Guard Research and Development Center has been directed under the Advanced Marine Vehicle (AMV) Project's 9207.2 Ship Test and Evaluation element to conduct simultaneous technical evaluations on two surface effect ships (SES). Side-by-side seakeeping and calm water power plant performance tests were conducted on the USN 160' SES-200 and USCG 110' CGC SEA HAWK (WSES-2) in the Atlantic Ocean south of Key West, Florida. An evaluation of the ride control system on the SES-200 was required to assess the utility of adding a similar system to a 110' Coast Guard SES in order to improve ride quality and reduce high frequency vertical accelerations which cause crew fatigue.

This data will be incorporated into the AMV data base to support the vessel evaluation and acquisition process. Performance information will also be utilized by headquarters personnel when evaluating proposed craft in the upcoming patrol boat and buoy tender replacement efforts. The Research and Development Center will also utilize the data as input for various operations analysis computer models which evaluate a vessel's ability to perform Coast Guard missions.

BACKGROUND AND DESCRIPTIONS

Surface Effect Ships (SES) are a catamaran-type hull which can operate at low speeds on its two side hulls like a displacement ship or cushionborne by pressurizing the region between the side hulls with air. When cushionborne the ship partially rides on its side hulls and on a drag-reducing cushion of air contained by the sidehulls and flexible bow and stern seals. When cruising on cushion the center portion of the hull is clear of

the water and supported by the air cushion and some reduced buoyancy from the side hulls. This configuration reduces the wetted surface area and thus decreases the resistance enabling higher speeds.

The air cushion exerts both a lift and a drag force on the hull as it moves over the water surface. The drag force, known as cushion wave making drag, represents a significant percentage of total SES resistance and hence, the required propeller thrust. Selection of cushion length-to-beam proportions is a fundamental part of SES design because the ratio of these dimensions determines the wave making resistance characteristics.

The Navy has been conducting research on the effect of length-to-beam proportions on SES performance, seakeeping and maneuvering since 1970. For ocean capable vessels, research showed that length-to-beam ratios of 4 to 1 or greater offer efficient operation at task force speeds without compromising the SES advantage of operating at significantly higher speeds. This balanced performance is attributable to shifting the peak of the high wave drag region known as "hump" to higher speeds outside the operating envelope. The name "High Length-to-Beam SES" has been given to these vessels to distinguish them from the previous generation of Navy SES which had lower length-to-beam ratios and has to be propelled through a high drag speed regime in order to attain efficient cruise speeds. The three 110' Coast Guard SES's are classified as low length-to-beam ratio vessels with a ratio of 2.65.

To validate high length-to-beam research, the Navy procured a 110' commercial Bell Halter, Inc. (BH) SES, the same class vessel the Coast Guard later purchased. After extensive testing, the Navy increased its length-to-beam ratio from 2.65 to 4.25 by installing a 50' hull extension amidships. This vessel is the SES-200.

The Coast Guard tested the Navy 110' SES in 1981 before it was extended to 160' (Reference 1). Subsequently, three 110' Bell Halter, Inc. SES's were purchased by the Coast Guard and placed into service in the newly formed SES Division out of Key West, Florida. These vessels have the same main engines as the SES-200 and a low cushion length-to-beam ratio of 2.65 compared to 4.25 of the SES-200. The CGC SEA HAWK must be propelled through hump (22 knots) in order to reach design speed of 28 knots while the SES-200 operates below the high wave drag hump speed which is in the 30+ knot range. The SES-200 has four lift engines, and the SEA HAWK has two of the same make and horsepower. Of the four fans driven by the lift engines on the SES-200, two are identical to the two centrifugal fans installed on the SEA HAWK.

Powering and seakeeping performances of the SES-200 and CGC SEA HAWK can be easily compared because they have identical power plants, seal systems, and midship section hull shapes. The propellers are slightly different. The m. 'or differences are the length-to-beam ratios, displacement, range and lift engine configuration where the SES-200 has two more lift engines which were added to support a larger cushion volume and displacement. A comparison of the principal characteristics and plan and profile views of the CGC SEA HAWK and SES-200 are presented in Table I and Figure 1.

TESTS AND DATA COLLECTION

The objective of this side-by-side technical evaluation was to quantify and compare the calm water power plant and rough water seakeeping performance of the two vessels. An evaluation of the USN SES-200 ride control system (RCS) was also conducted during all seakeeping tests. A similar RCS is being considered for installation on one of the Coast Guard SES's. Human response to ship motions were studied mainly on the CGC SEA HAWK.

TABLE I

COMPARISON OF USCGC SEA HAWK (WSES-2) AND USN SES-200
PRINCIPAL CHARACTERISTICS

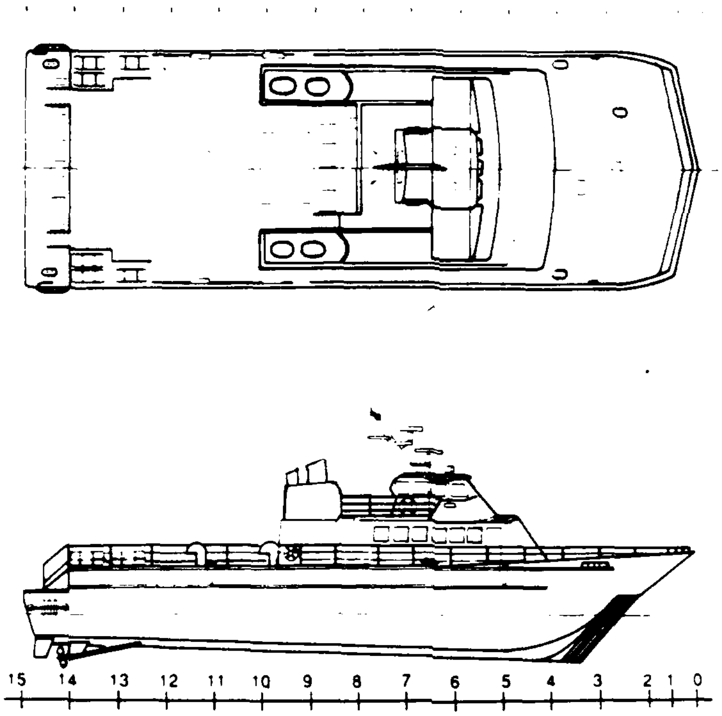
LIST OF PARTICULARS

Type	CGC SEA HAWK	USN SES-200
Length, Overall	109 ft. 3/4 in.	159 ft. 1 in.
Beam, Overall	39 ft. 0 in.	Same
Length, Cushion	83 ft. 2-1/2 in.	133 ft. 4 in.
Beam, Cushion	31 ft. 9-1.2 in.	Same
Cushion Length/Beam Ratio	2.65	4.25
Cushion Area	2644 $ft.^2$	4236 $ft.^2$
Max. Draft, On Cushion 3.5 Deg. Bow-up Trim	5 ft. 6 in.	Same
Max. Draft, Off Cushion Max., 0 Deg. Trim	9 ft. 3 in.	Same
Displacement, Light	130 long tons	150 long tons
Displacement, Max.	150 long tons	205 long tons
Fuel Capacity (100%)	23.8 long tons (7342 gal.)	59.6 long tons (18,389 gal.)
Design Speed, On Cushion	30 knots, sea state 0 25 knots, sea state 3	Same
Design Range, On Cushion	1100 nm in sea state 3	2200 nm in sea state 3
Hull Construction	Welded Aluminum (5086)	Same
Crew	18 (2 officers, 1 chief petty officer, 15 enlisted)	Same
Main Engines	Two Detroit Diesel 16V-149TI 1600 shp at 1900 rpm	Same

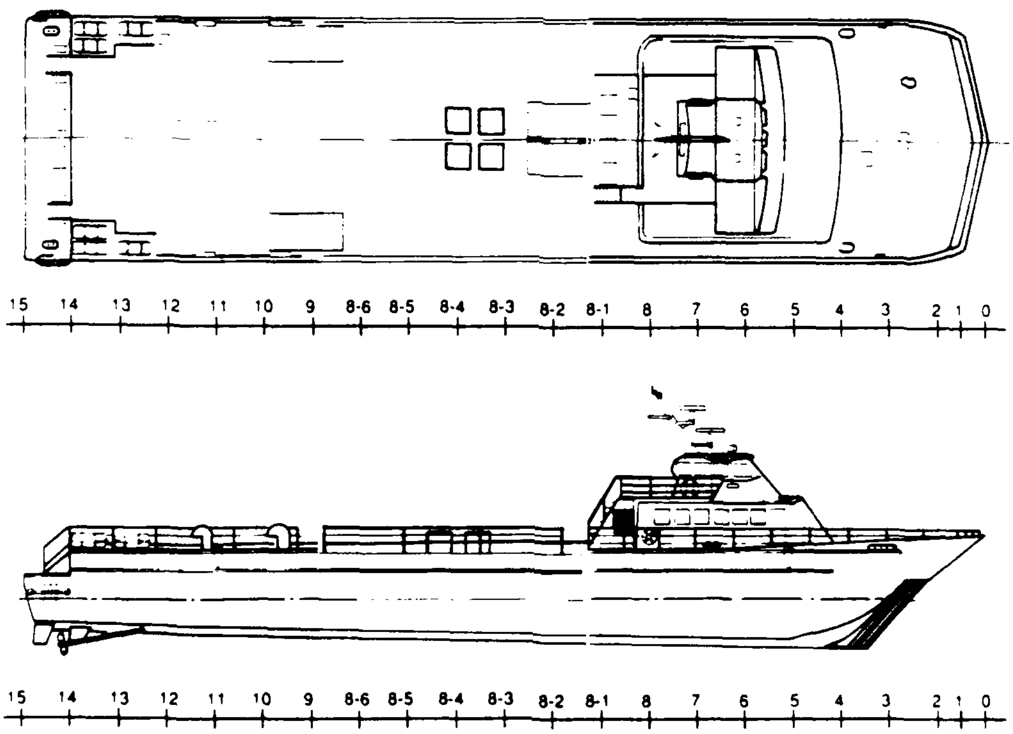
TABLE I (continued)

LIST OF PARTICULARS

Type	CGC SEA HAWK	USN SES-200
Reduction Gears	Two ZF Model BW455, 2:1 ratio	Same
Propellers	Two Three-bladed 42" dia by 49" pitch	Two three-bladed 40" dia by 48" pitch
Lift Engines	Two GM 8V-92 diesel 350 shp at 2100 rpm	Four (Same)
Lift Fans	Two Bell 40" dia centrifugal fans	Two (Same) Two Neu LILLE FRANCE rotating diffuser fans
Bow Seals	Two-dimensional elastomer-coated fingers (8 total)	Same
Stern Seals	Three lobe elastomer-coated bag	Same
Steering	Twin rudder, differential thrust and reverse with propellers	Same



CGC SEA HAWK



SES-200

FIGURE 1. SES PLAN AND PROFILE VIEW

Tests

Tests defined herein are referenced by number relating to the USCG Research and Development Center's "General Test Plan for Marine Vehicle Testing (GTP)". Table II is a list of all tests conducted during the technical evaluation. Details of the test procedures can be seen in the GTP (Reference 2).

Data Collection

Data was collected utilizing identical sensors and data Oacquisition systems on both vessels. A computerized data acquisition system with analog tape recorder backup was used to collect ship motion, cushion pressure, shaft rpm, torque and horsepower information. Sound level readings and in-line fuel flow measurements were recorded by hand. Human responses to ship motion were measured two ways each with self-recording and documenting capability. Two engineers from the National Aeronautics and Space Administration (NASA) conducted measurements on the SEA HAWK using their ride quality meter. The second method utilized International Standard Organization (ISO) vertical acceleration standards. A directional wave buoy was deployed from the SEA HAWK before and after seakeeping tests. It transmitted wave height and buoy tilt North-South and East-West to the receiver on the vessel. On board SEA HAWK, a microcomputer analyzed the buoy data for significant wave height directionality and frequency components of the wave field. This directional information assisted the test directors in choosing the desired headings during seakeeping runs. Figure 2 presents the data acquisition equipment systems used on both vessels. Test equipment specifications are listed in Appendix A.

Engine Performance

Main engines and lift engines were outfitted with in-line fuel flow meters. Flow into and return flow from the diesels

TABLE II

TESTS CONDUCTED

GTP Test No.	Description
1	Principal Characteristics
13*	Side-by-side motions in waves and in calm water. Wave heights 3-6 feet at the maximum sustained speed of the slowest vessel approximately 23 knots. These tests were conducted with and without the ride control system activated on the SES-200. Vertical accelerations on the bridge, Center of Gravity (cg), berthing area and mess deck on both vessels were measured along with roll and pitch angles and rates.
38	Cushion pressure (concurrent with ship motions runs).
3	Speed vs Power in calm water.
4	Fuel consumption and endurance in calm water.
37	Human fatigue response to ship motions. Two discomfort standards were utilized and results compared using the NASA ride quality meter and the Bruel and Kjaer Human response meter on the CGC SEA HAWK.
24	Noise levels (concurrent with speed and power tests).
7	Tactical Data (USCGC SEA HAWK only)

* Tests conducted side-by-side

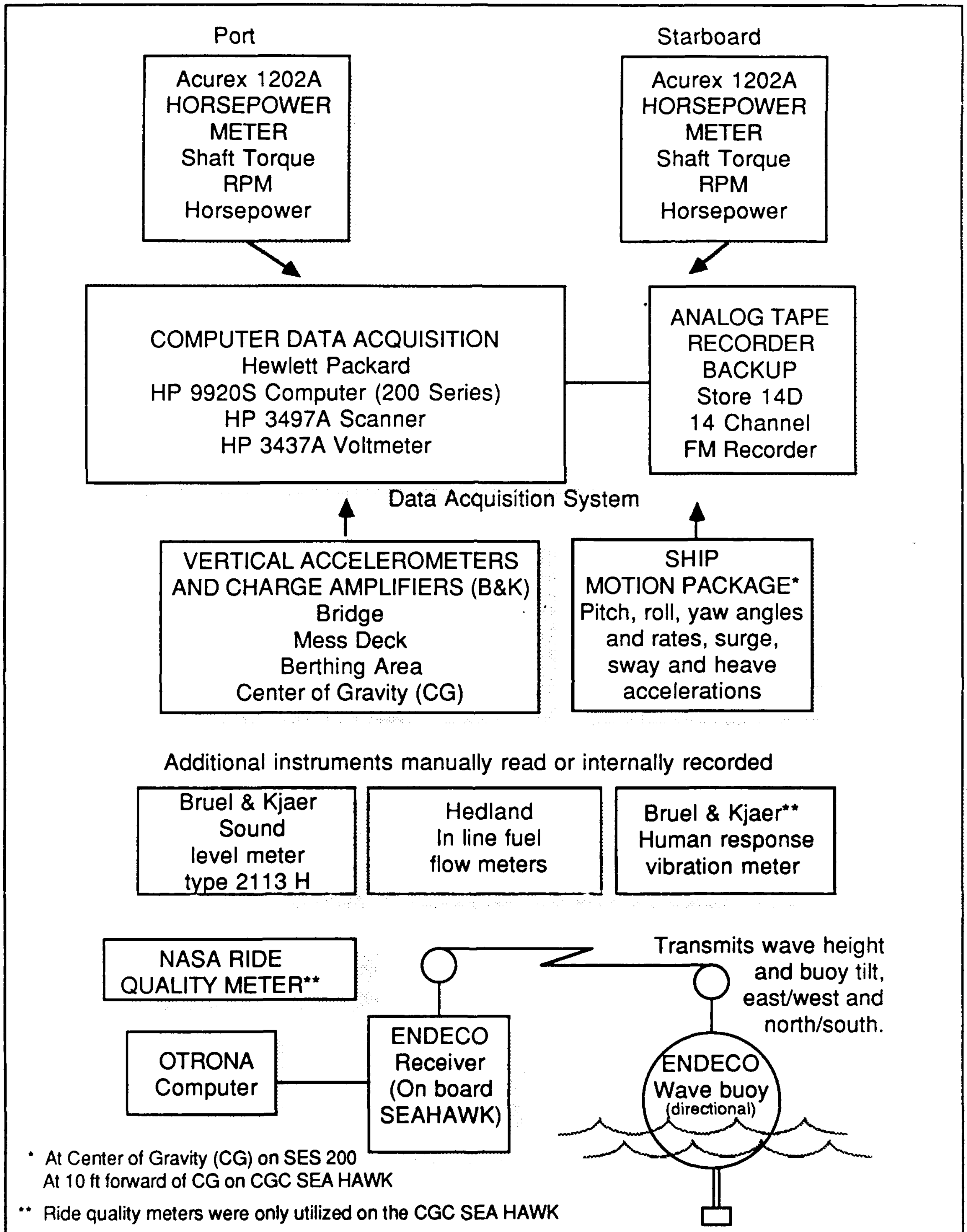


Figure 2. BLOCK DIAGRAM OF DATA ACQUISITION SYSTEMS ON BOTH VESSELS

were measured and recorded for each rpm level incrementally increased during the power plant testing. Shaft torque was measured with strain gauges epoxied to both main shafts at the closest possible point to hull penetration as seen in Figure 3. The Acurex system transmitted the torque signals from the shaft to the antenna surrounding the shaft using FM telemetry and processed the signals along with shaft rpm transducer outputs to compute shaft horsepower. The system is calibrated utilizing a shunt resistor simulating a known strain level across the strain gauge bridge. Speed/power/fuel consumption tests were conducted independently on both vessels in calm water. The horsepower (HP) meters were transferred to the SEA HAWK after the SES-200 was tested since only two HP meters were available for testing.

Horsepower

Both ships were at displacements considered medium to heavy range during speed/power/fuel consumption tests. Shaft horsepower tests verified that the SES-200 is operating below primary hump speed as expected. The SEA HAWK, which is designed to operate above hump speed at speeds greater than 22 knots, was not able to exceed this speed. This has been a problem with the three Coast Guard SES's which have been loaded down by additional equipment and structural weight since their commissioning. Although the 16V Detroit Diesels on both vessels are identical, the SES-200 was able to extract more horsepower from them than the SEA HAWK as seen in Figure 4 and Tables B-I and B-II. This may be attributed to slightly different propellers and hull/cushion resistance characteristics. The CGC SEA HAWK has never attained more than 1300 shaft hp at 1617 rpm during this and one previous evaluation on engines rated at 1600 shp at 1900 rpm. Recently after this evaluation, the engines were modified on all three Coast Guard SES's to obtain an additional 200 shp each. The SES's can now routinely attain speeds of 26-30 knots.

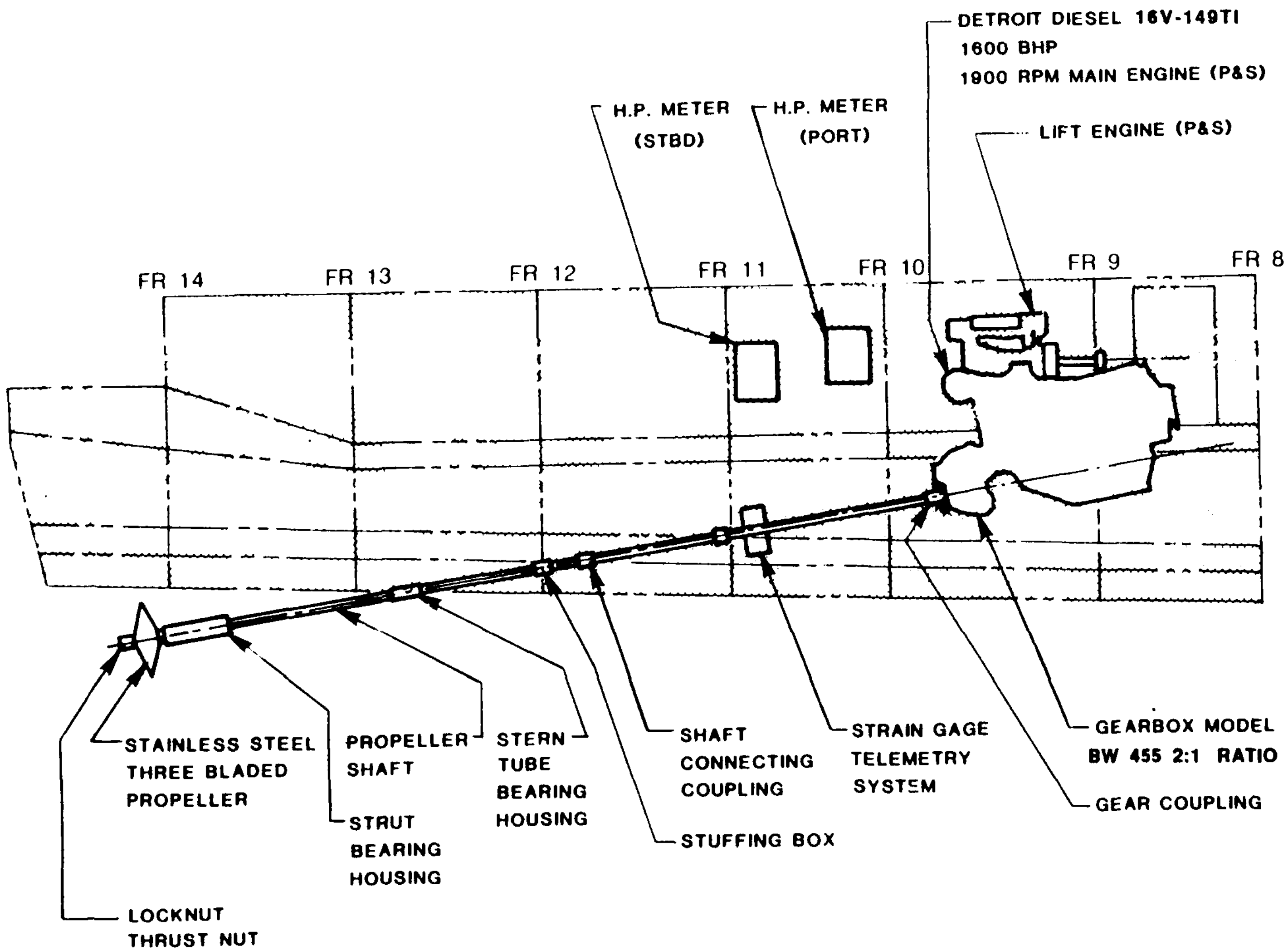


Figure 3. PROPULSION SYSTEM (Port & Starboard) WITH TORQUE & RPM MEASUREMENT INSTRUMENTATION

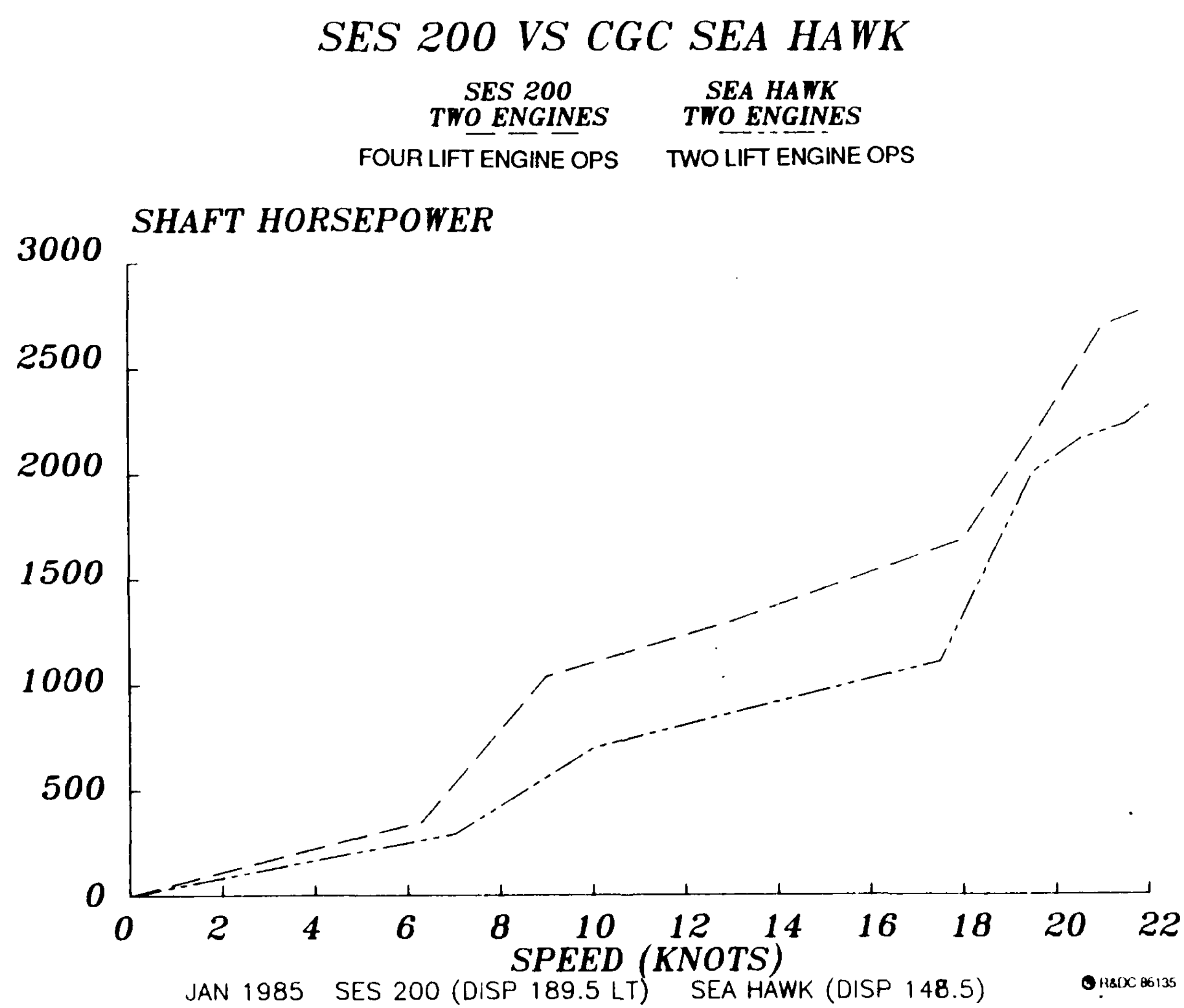


Figure 4. COMPARISON OF SHAFT HORSEPOWER

Sidehull, rudder and seal drag on a SES typically increases linearly with speed while cushion wave drag has one small secondary hump and one large primary hump at a higher speed. The secondary hump speed is seen in Figure 4 at 8-10 knots for both vessels. The crest of the primary drag hump for the SEA HAWK is seen at 18-22 knots.

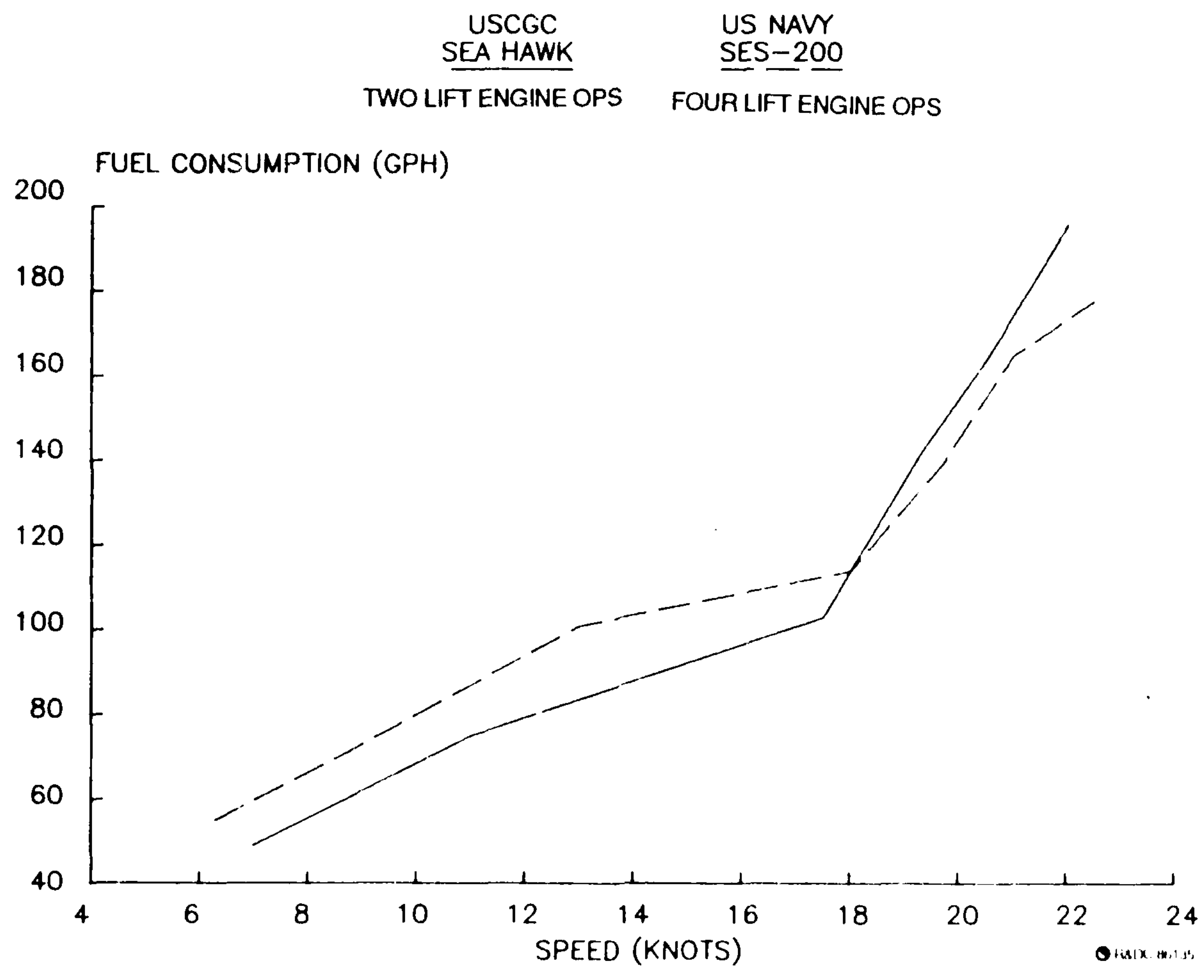
During the two week test period, the SES-200 was able to go approximately two knots faster than the SEA HAWK, while 50 foot longer and 46 long tons heavier, for one main reason. The SES-200 does not have to transit primary hump speed as the SEA HAWK must at 22 knots, because its high cushion length to beam ratio of 4.25 causes that hump to exist a speed above its design speed (30+ knots). The geometry of the hull being 50 feet longer allows it to plane out at approximately 1.5 degrees up by the bow while the SEA HAWK planes at 3.5 degrees trim up. This lower planing attitude may enable the propellers to be more efficient in developing usable thrust on the SES-200.

Care should be taken to ballast the vessels properly to adjust the longitudinal center of gravity to obtain optimum trim operation. The 110' surface effect ship operator's manual states: "For best performance and most comfortable ride, the vessel should be loaded to place the longitudinal center of gravity (cg) approximately 1.5 feet aft of amidships, and the lateral cg on the centerline. This cg location will result in a trim of 3 to 4 degrees bow up deck angle at cruise and zero heel." Trim adjustments are controlled by ballasting and can make the difference as to whether or not the vessel can transit and remain above hump speed (22 knots).

Fuel Consumption/Range

As seen in Figure 5, the SEA HAWK consumes less fuel than the SES-200 at low speeds; however, above 18 knots the SES-200 consumes less fuel. This relates to the hump drag speed which

USCGC SEA HAWK WSES-2 / US NAVY SES-200



JANUARY 1985, TWO ENGINE OPS. (SEA HAWK 148.5 LT, SES-200 189.5 LT)

Figure 5. TOTAL FUEL CONSUMPTION vs SPEED

the SEA HAWK must overcome in the 18-22 knot range in order to get to the most economical operating speeds in the 23-28 knot range. The SES-200 always operates at speeds below primary hump speed which exists in the 30+ knot range.

When the Navy 110' SES-160 was stretched 50 feet and became the SES-200, it was modified to carry an additional 11,000 gallons, 60% more fuel. This extra fuel capacity along with the fuel efficiency gained due to reduced wave drag when the vessel was lengthened provides the SES-200 with far superior range and endurance over that of the CGC SEA HAWK as seen in Figures 6 and 7. This change also improved the ride quality and is discussed in detail in the Side-by-Side Seakeeping section.

Fuel efficiency is defined here as the number of gallons consumed per nautical mile traveled (gal/nm). Both SES's tested exhibited small changes in fuel efficiency over their entire speed range compared to conventional displacement hulls which dramatically lose efficiency at high speeds. It is clear that SES's should be operated at top speeds since there is not a significant fuel efficiency advantage to run at moderate or slow speeds. At speeds above 18 knots, the SES-200 is more fuel efficient than the SEA HAWK, as seen in Figure 8. Fuel consumption, range, and fuel efficiency data tables for the SEA HAWK and SES-200 are presented in Appendix B, Tables B-III through B-VI, respectively.

Noise Levels

A sound survey was conducted on both vessels during the speed/power runs in calm water. Both vessels exceed OSHA standards in all engine room and some living compartments at high speeds. It may be prudent to have personnel sleeping in after berthing compartments on the SEA HAWK wear some type of ear protection during high speed transits. Additional sound proofing of the bulkhead between the engine room and the berth-

USCGC SEA HAWK WSES-2 / US NAVY SES-200

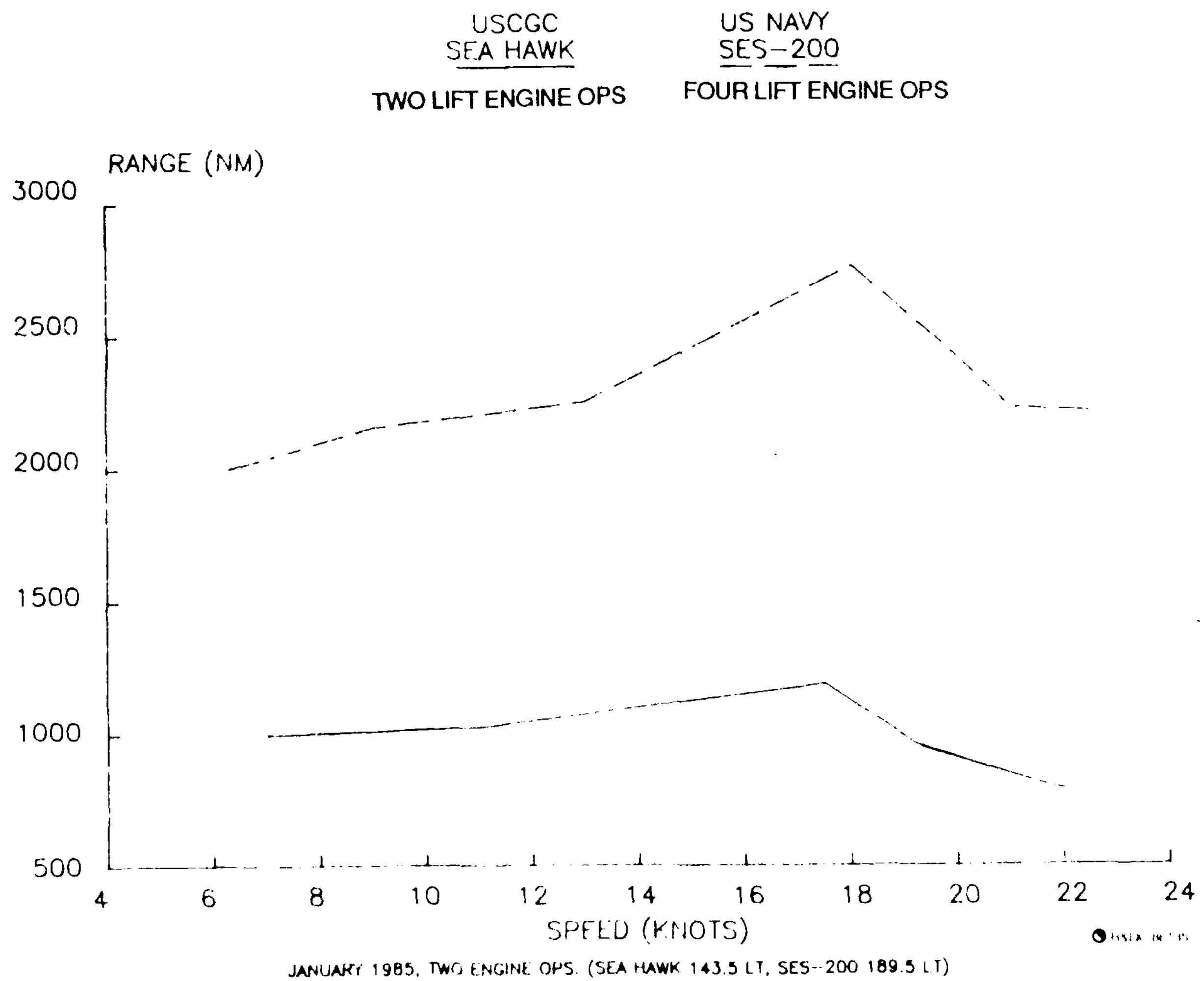


Figure 6. RANGE vs SPEED

USCGC SEA HAWK WSES-2 / US NAVY SES-200

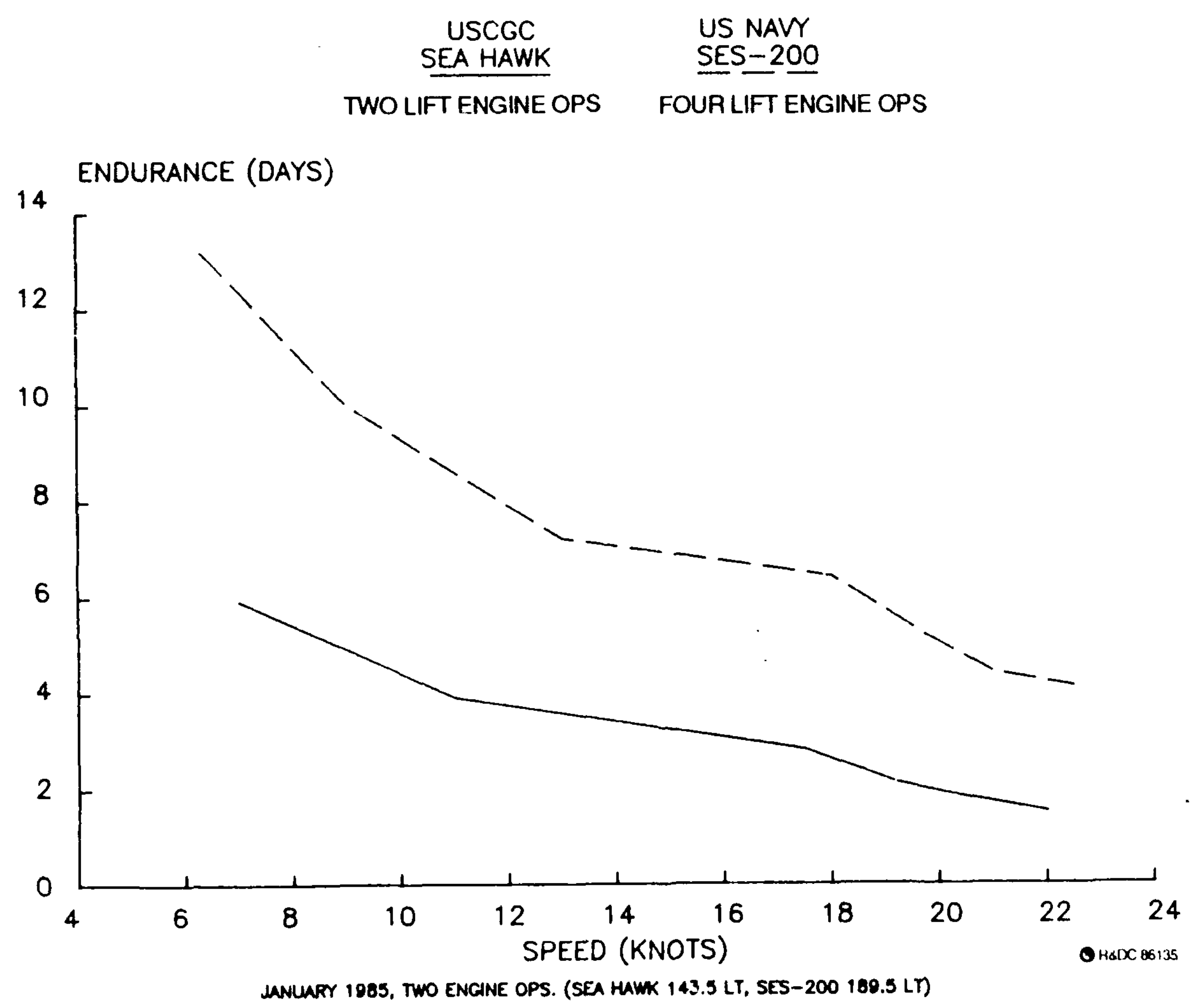


Figure 7. ENDURANCE vs SPEED

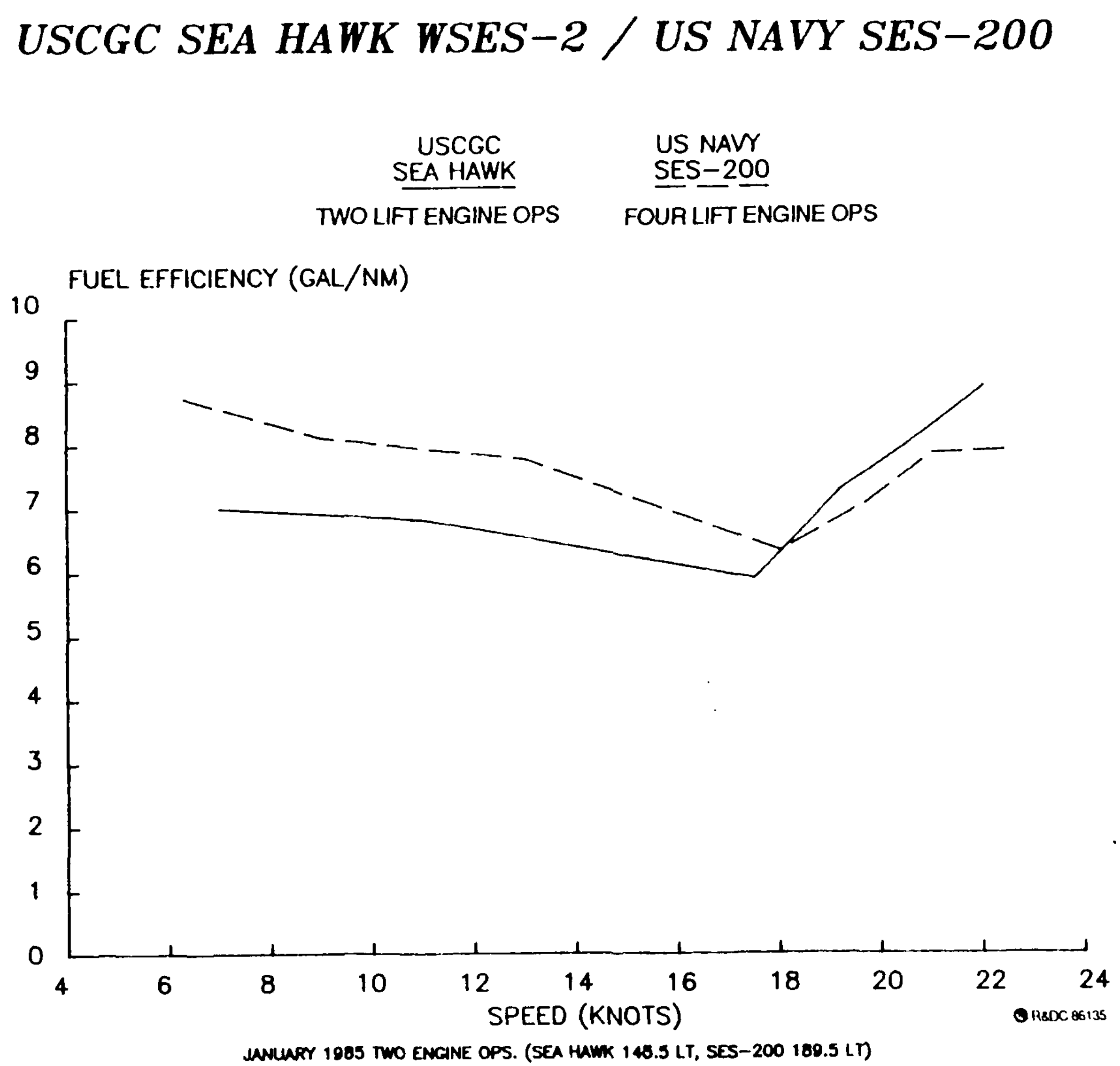


Figure 8. FUEL EFFICIENCY vs SPEED

ing area would improve the situation. Noise levels for both vessels in selected compartments are plotted along the OSHA standard 29 CFR 1910 noise endurance curve in Figure 9. More data is presented in Appendix B, Tables B-VII and B-VIII.

Tactical Data

Constant power rudder turns were performed on the CGC SEA HAWK; however, the data was not collected on the SES-200 because it was already completed by previous Navy testing. The procedure followed was to set the engines on matched rpm levels to attain the desired speed. All tests were done on cushion. They were started on a straight base course and the helm was shifted to the desired rudder angle of 10, 20 or 30 degrees and maintained throughout a 360 degree turn.

A RAYNAV 750 Loran receiver was utilized to determine ship's position. A computer program collected data on the ship's position every four seconds and plotted the turns on the computer terminal screen. The computer operator marked when the rudder was shifted and at the 90 degree and 360 degree course changes.

The SEA HAWK, like any SES, tends to side slip more than conventional displacement crafts in high speed turns. For that reason, additional data is presented to document this. The traditionally defined advance and transfer of the vessel at the standard 90 degree yaw angle (course heading) change is presented along with the "Maximum" path advance and transfer distances measured to the point where the path of the ship reaches a 90 degree change from base course. This is defined in a typical turning path plot, Figure 10. CGC SEA HAWK tactical data is presented in Table B-IX. The SES-200 tactical data extracted from Reference 3 is presented in Table B-X.

At 20 knots the SEA HAWK has much smaller tactical diame-

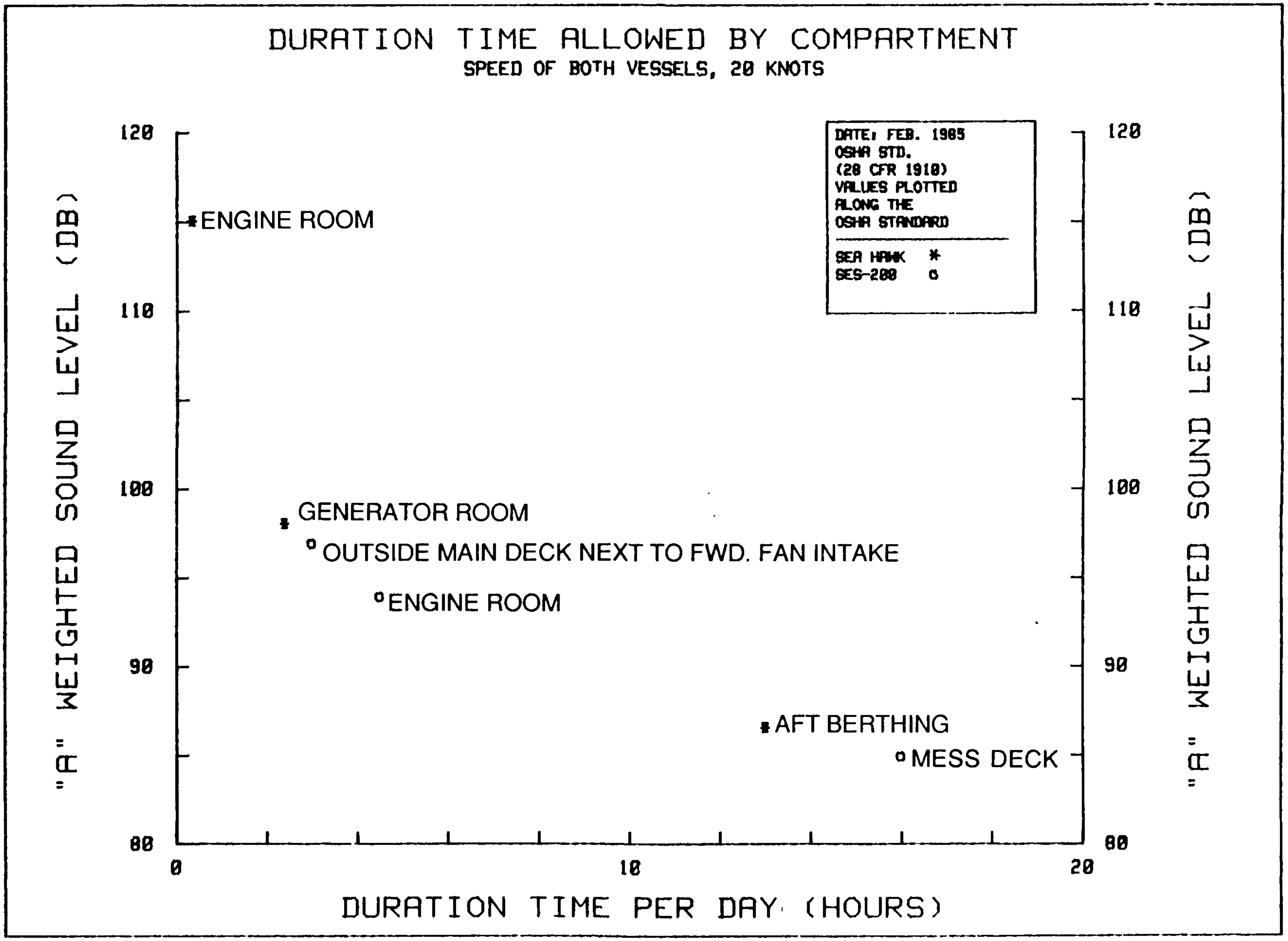


FIGURE 9. SOUND LEVEL EXPOSURE LIMITS FOR SELECTED COMPARTMENTS

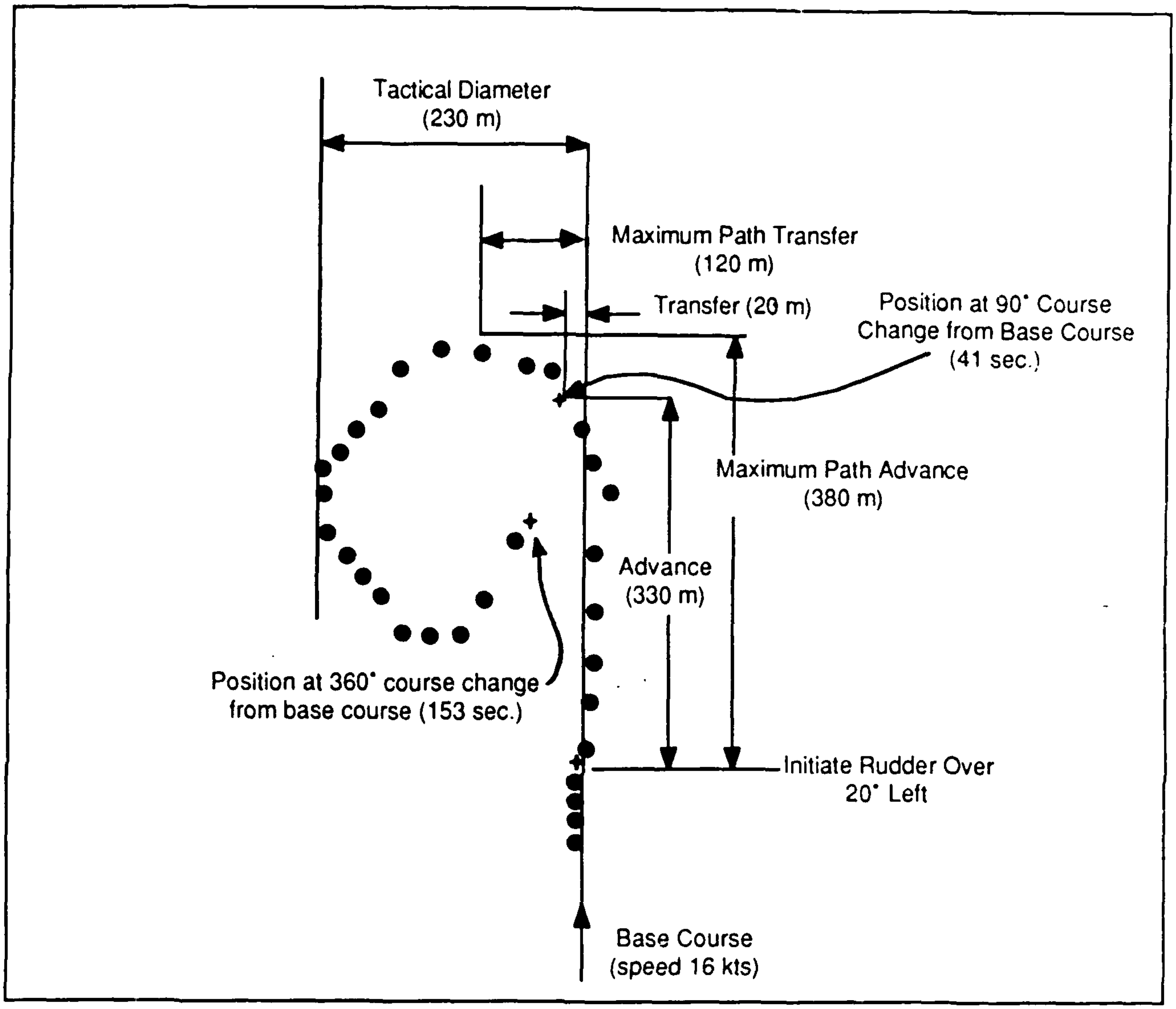


FIGURE 10. TYPICAL TURNING PATH PLOT OF CGC SEA HAWK

eters than the SES-200. At 30 degrees rudder, SEA HAWK tactical diameters are approximately 50% smaller, while at 10 degrees rudder, the SEA HAWK has tactical diameters 70% smaller than those of the SES-200.

Side-by-Side Seakeeping

The USCGC SEA HAWK and USN SES-200 were operated side-by-side during four seakeeping test days. Identical sensor packages and data acquisition systems were used on both vessels. An Endeco directional wave buoy was deployed by the SEA HAWK before and after each test period in order to define the wave environment. The objective of these tests were to compare the seakeeping characteristics of both vessels proceeding side-by-side at the same cruise speed in five different orientations to the major swell direction; head, bow quarter, beam, stern quarter, and following seas. All seakeeping data is presented in Appendix B, Tables B-XI to B-XVIII. Directional 3-D wave energy and wave power spectral density (PSD) plots for each seakeeping test are presented in Figures B-XIX to B-XXVIII.

The vessels proceeded side-by-side, 100 to 400 yards apart, at the fastest speed attainable by both vessels (approximately 20 knots). Data was collected for 20 to 30 minutes during each of the five seakeeping legs. The SES-200 ride control system (RCS) was evaluated during these seakeeping runs by operating with the system off for half of each leg of the course, then on. Although data tables and graphs are presented here for both ride conditions (RCS on and off), the discussion of RCS effectiveness is presented in the section entitled "SES-200 Ride Control System Evaluation". The RCS effects are not addressed in this section so that there is a clear determination of the ride quality gained by the larger length, displacement, and cushion length-to-beam ratio of the SES-200 compared to the CGC SEA HAWK.

Sensors were placed on both vessels as indicated in Figures 11 and 12. The ship motion package on the SEA HAWK could not be placed at the center of gravity (cg) because its large cables could not be run through water-tight doors. It was placed ten feet forward of the cg. In order to compensate for this, a separate vertical accelerometer was placed at the cg. It is assumed that surge and sway accelerations measured in the motion package ten feet forward of the cg are not significantly different from those at the cg.

In addition to the motion package sensors, accelerometers were hard mounted vertically on the bridge, mess deck, berthing area, and at the center of gravity as previously mentioned. In this way, a comparison of motions at equivalent operational sites on the vessels could be made. Note that the bridge, mess deck, and berthing areas of the SES-200 are further away from the cg when compared to those spaces on the SEA HAWK (shown in Figures 11 and 12.) This is a result of the 50 foot section which was added to the SES-200 just forward of the original 110' configuration longitudinal center of gravity between frames 8 and 9.

There were some sensor malfunctions during the test period; however, none made a significant impact on the seakeeping data because redundant vertical accelerometers were utilized, as well as a replacement ship roll angle gyro. Two vertical accelerometers, located on the mess deck and berthing area on the SES-200, did not operate properly. Since accelerometers at the cg and bridge functioned well and bracketed the two malfunctioning sensors located between them, there was no significant loss of information. The roll angle sensor in the SEA HAWK motion package was discovered drifting excessively during the first test day underway. It was replaced by a backup motion package roll angle gyro.

The first test day underway, 27 January 1985, was utilized

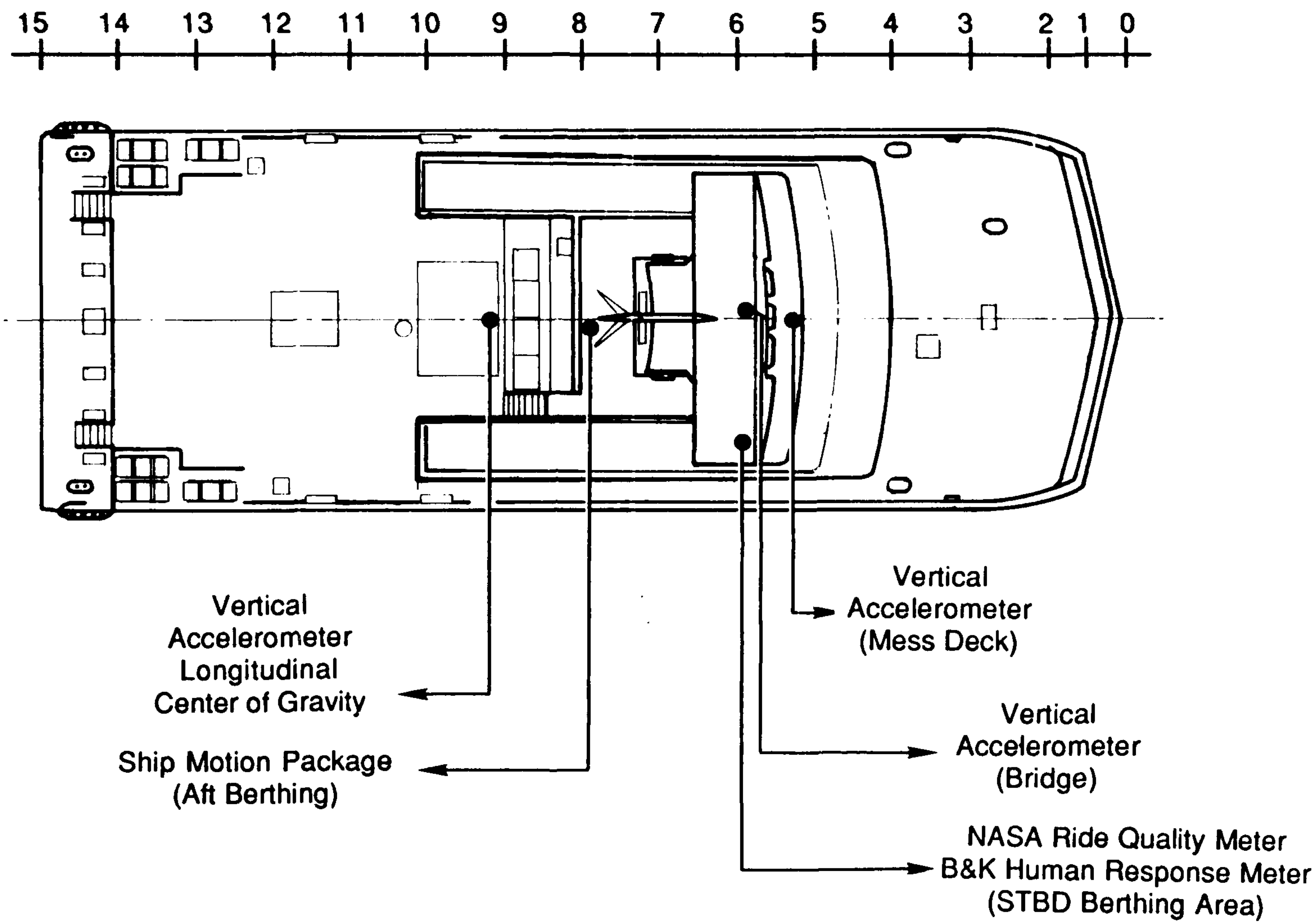


FIGURE 11. CGC SEA HAWK SENSOR LOCATIONS

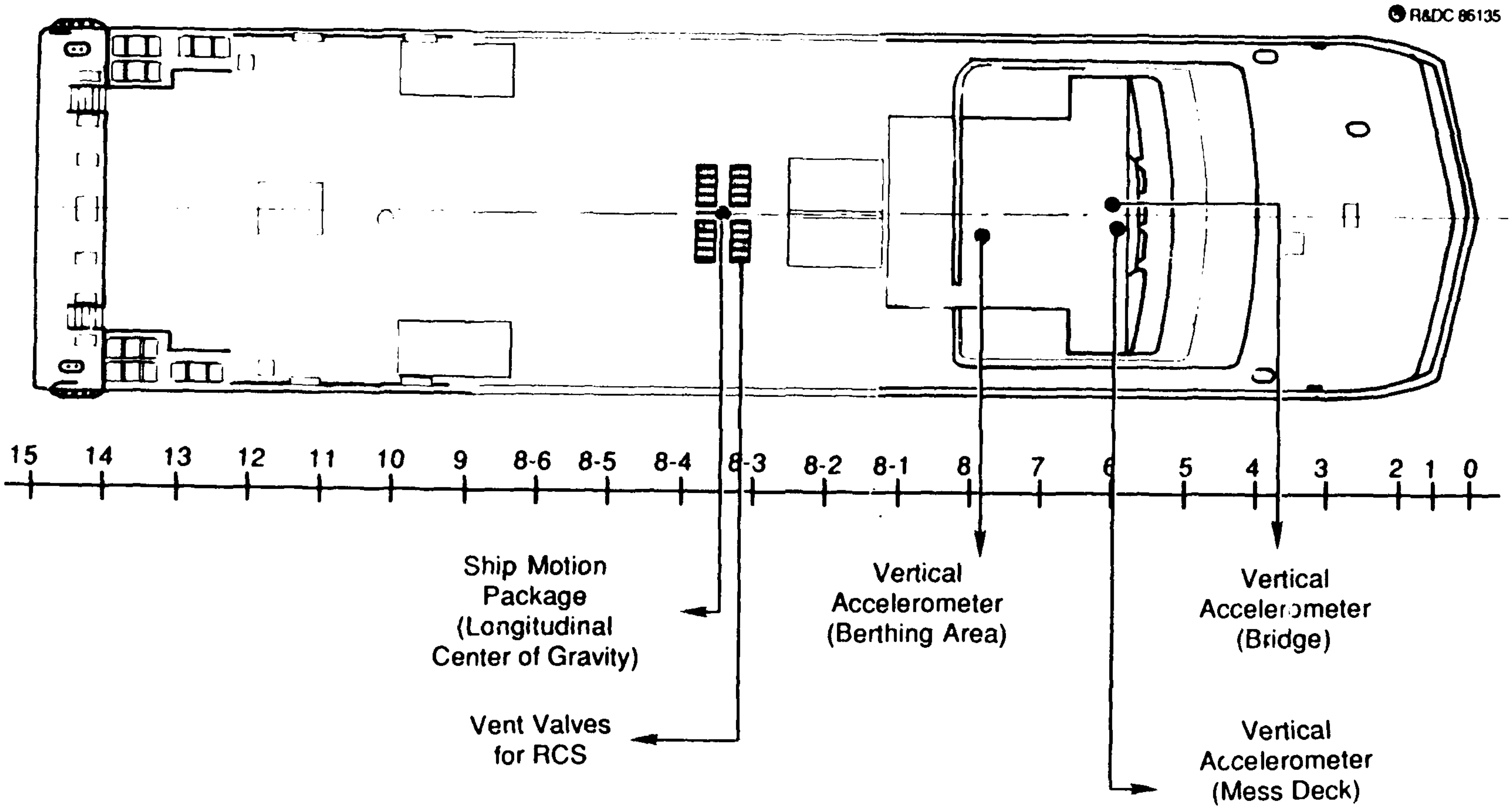


FIGURE 12. USN SES-200 SENSOR LOCATIONS

as a shake down seakeeping cruise to check out all sensors, data acquisition hardware and software. Although there were some equipment problems this first day out, in addition to a disrupted schedule because of a law enforcement case, some useful data was collected at 18 knots in 3.5 to 4.4 foot significant waves. This seakeeping data is presented in tabular form in Appendix B, Tables B-XI and B-XII. Wave PSD and direction data collected is presented in Figures B-XIX and B-XX for 4.4 foot unidirectional seas.

The second seakeeping test day was conducted in relatively calm water. For this reason, only head seas runs were conducted on 28 January in 4 second period, 2.2 foot significant waves. Seakeeping data for both vessels is presented in Table B-XIII. Vertical accelerations at the cg on the SES-200 are substantially less than compared to the SEA HAWK, even though the seas were relatively calm. Wave PSD and direction plots are presented in Figures B-XXI and B-XXII.

Seakeeping runs were conducted at 20 knots, in five directions relative to the major swells, in 4.0 foot significant seas on the morning of 31 January 1985. Results are presented in Table B-XIV and Table B-XV. Roll, pitch, and heave on the SES-200 were generally less than that on the SEA HAWK; however, there are some exceptions at certain headings. Polar plots are used to present a comparison of ride quality results relating to ship motions at various headings relative to major swells. Figures 13-15 graphically show the ship motion response to 4 foot seas of both vessels. Surge acceleration on the SES-200 was 4.5 to 5 times higher than that experienced on the SEA HAWK in bow quarter and head sea runs. This was not expected. It is unusual in ship tests to get higher surge accelerations than vertical accelerations at the cg. This was very often the case during the test period on the SES-200 in head and bow quarter seas runs. Test team members noted that surging motion often required them to hold on during seakeeping runs on the SES-200.

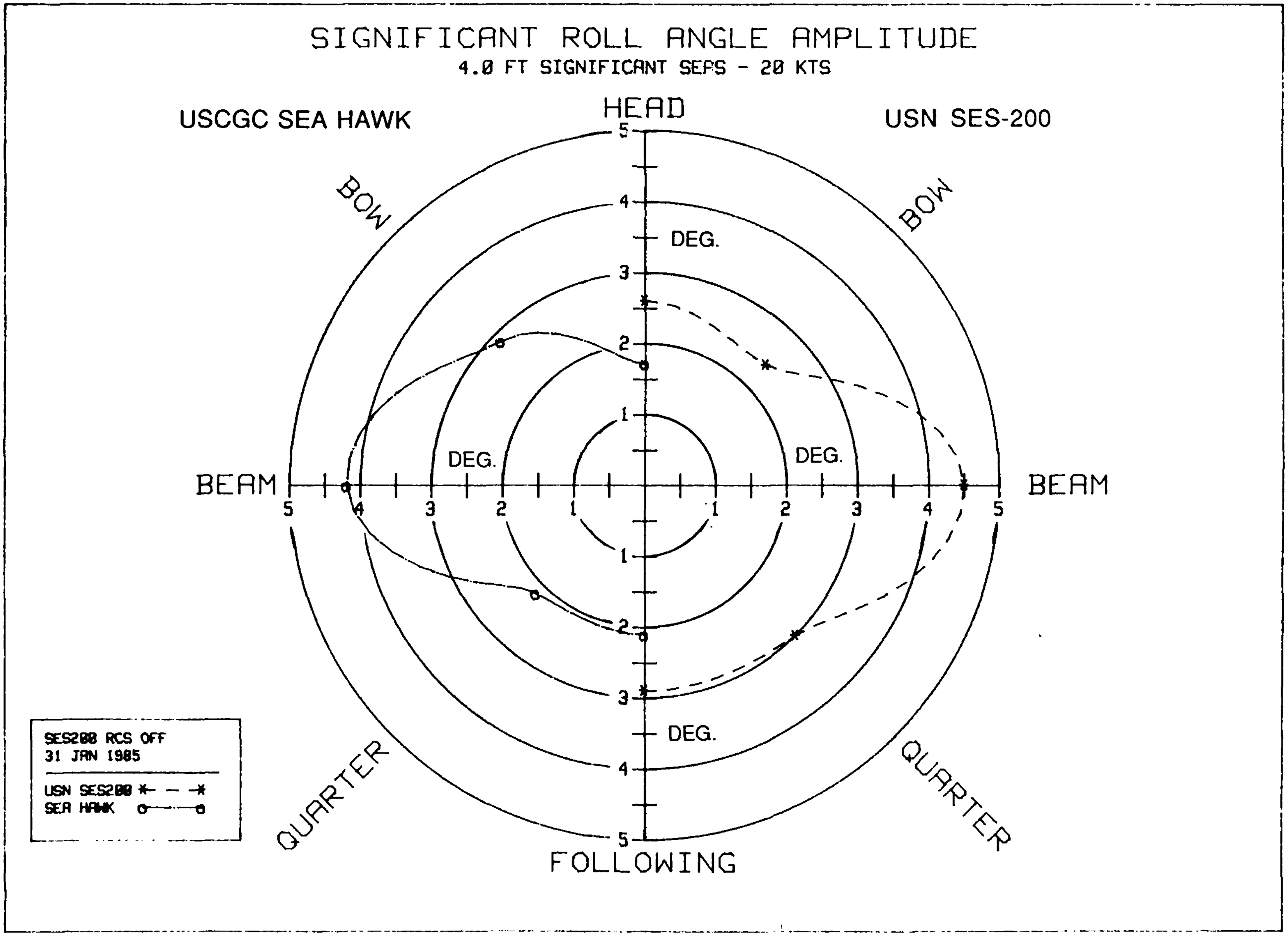


FIGURE 13. POLAR PLOT COMPARISON OF ROLL ANGLE IN 4 FT. SEAS, 31 JAN 1985

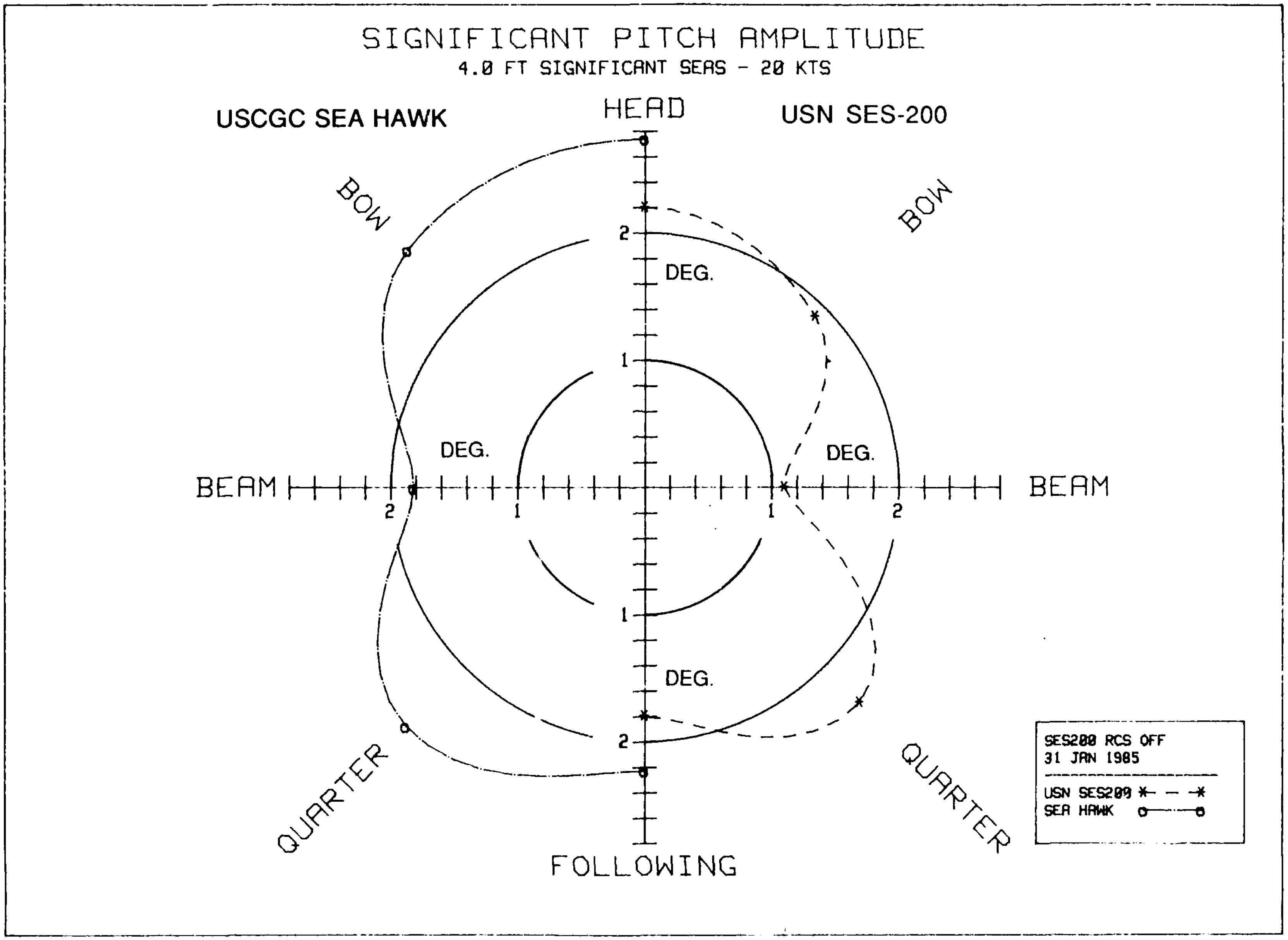


FIGURE 14. POLAR PLOT COMPARISON OF PITCH ANGLE IN 4 FT. SEAS, 31 JAN 1985

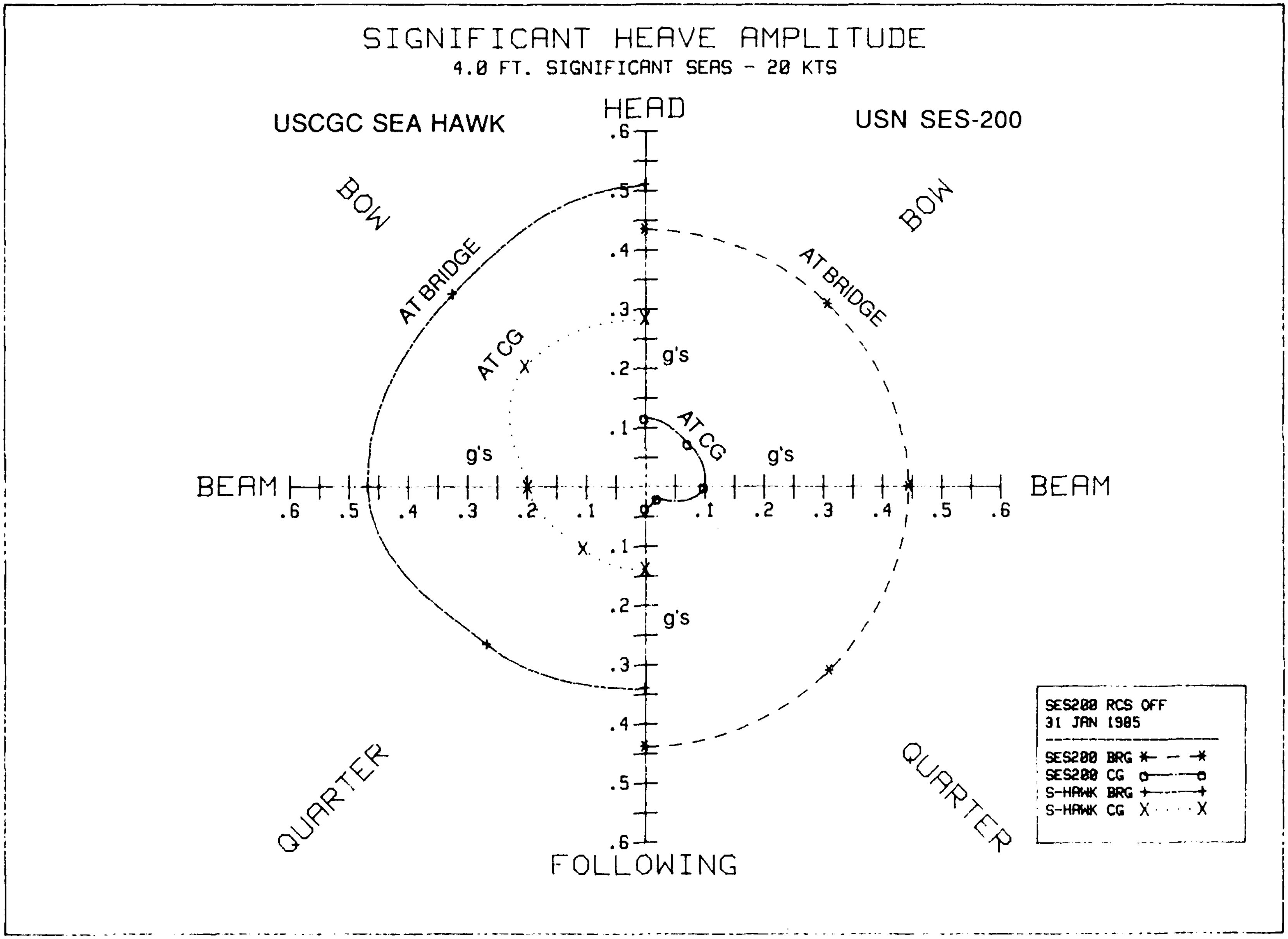


FIGURE 15. POLAR PLOT COMPARISON OF HEAVE ACCELERATION IN 4 FT. SEAS, 31 JAN 1985

The RMS surge on the SEA HAWK was 11% of its heave in head seas, while surge was 127%, or 27% greater than the heave value on the SES-200 at its cg. Wave PSD and direction information is presented in Figures B-XXIII and B-XXIV. The seas were multi-directional as seen in Figure B-XXIV.

The sea state increased the afternoon of 31 January, and additional testing was completed in 6.4 foot significant unidirectional seas, Figures B-XXV and B-XXVI. The three dimensional directional wave data plotted in Figure B-XXVI shows the unidirectional characteristics and wave period content of the seas. Both vessels conducted head seas runs. The runs were conducted thirty minutes apart because of engineering problems on one vessel; however, they are compared since the sea state did not substantially change in that short period of time. The SES-200 continued to do additional seakeeping runs at other headings in order to evaluate the ride control system in heavy seas. All of the seakeeping data for both vessels is presented in Table B-XVI.

Vertical accelerations measured on the SEA HAWK increased substantially from the morning runs in 4 foot seas when compared to afternoon runs in 6.4 foot seas, while the SES-200's accelerations rose only slightly. During two head seas runs in 4 and 6.4 foot seas, vertical accelerations on the SES-200 increased 4% at the cg and 1% on the bridge, while vertical accelerations on the SEA HAWK increased by 27% at the cg and 15% on the bridge.

The last seakeeping test day was completed in 3.4 to 3.9 foot significant seas. The seakeeping data obtained in side-by-side tests conducted on 2 February 1985 are presented in Tables B-XVII and B-XVIII. Wave PSD and direction plots are presented in Figures B-XXVII and B-XXVIII for 3.9 foot seas. The same trend of vertical acceleration on the SES-200 being less than accelerations at corresponding locations on the SEA

HAWK continued; however, the difference between accelerations at the cg and bridge of those vessels is quite different. In head seas RMS heave accelerations on the SEA HAWK bridge are only 24% higher than those on the SES-200 with RCS off, while accelerations at the SEA HAWK cg are 120% higher. This trend is consistent for all head and bow quarter seakeeping runs conducted and can be seen in Figure 16 for the 3.4 foot head seas run.

The bridge on the SES-200 is approximately 39 foot forward of the cg compared to 26 foot forward of the cg on the SEA HAWK. Vertical acceleration on the bridge is comparable to the whole body acceleration encountered at the cg plus the acceleration caused by the pitch action of the vessel which pivots close to the cg. The further forward from the cg you are, the more vertical acceleration is encountered. The vertical acceleration at all comparative selected sites is less on the SES-200 due to larger displacement and greater hull/water dampening than the SEA HAWK. The acceleration differences are not as great on the bridge as they are at the cg, because the bridge on the SES-200 is further forward of the cg than the relative bridge location on the SEA HAWK.

Cushion pressure was measured on both vessels. Nominal mean cushion pressure is 0.54 PSI on the SES-200 and 0.65 PSI on the SEA HAWK. Less pressure is required on the SES-200 for several reasons. Although the SES-200 is about 25% heavier, it has 37% more cushion area and also more buoyancy created by the additional 50 foot section of the two side hulls.

USCGC SEA HAWK Ride Quality Evaluation

Two methods were utilized to quantify the ride quality of the CGC SEA HAWK. A similar analysis of the SES-200 was not conducted because it is not an operational cutter in Coast Guard service and duplicate equipment was not available. Ride quality

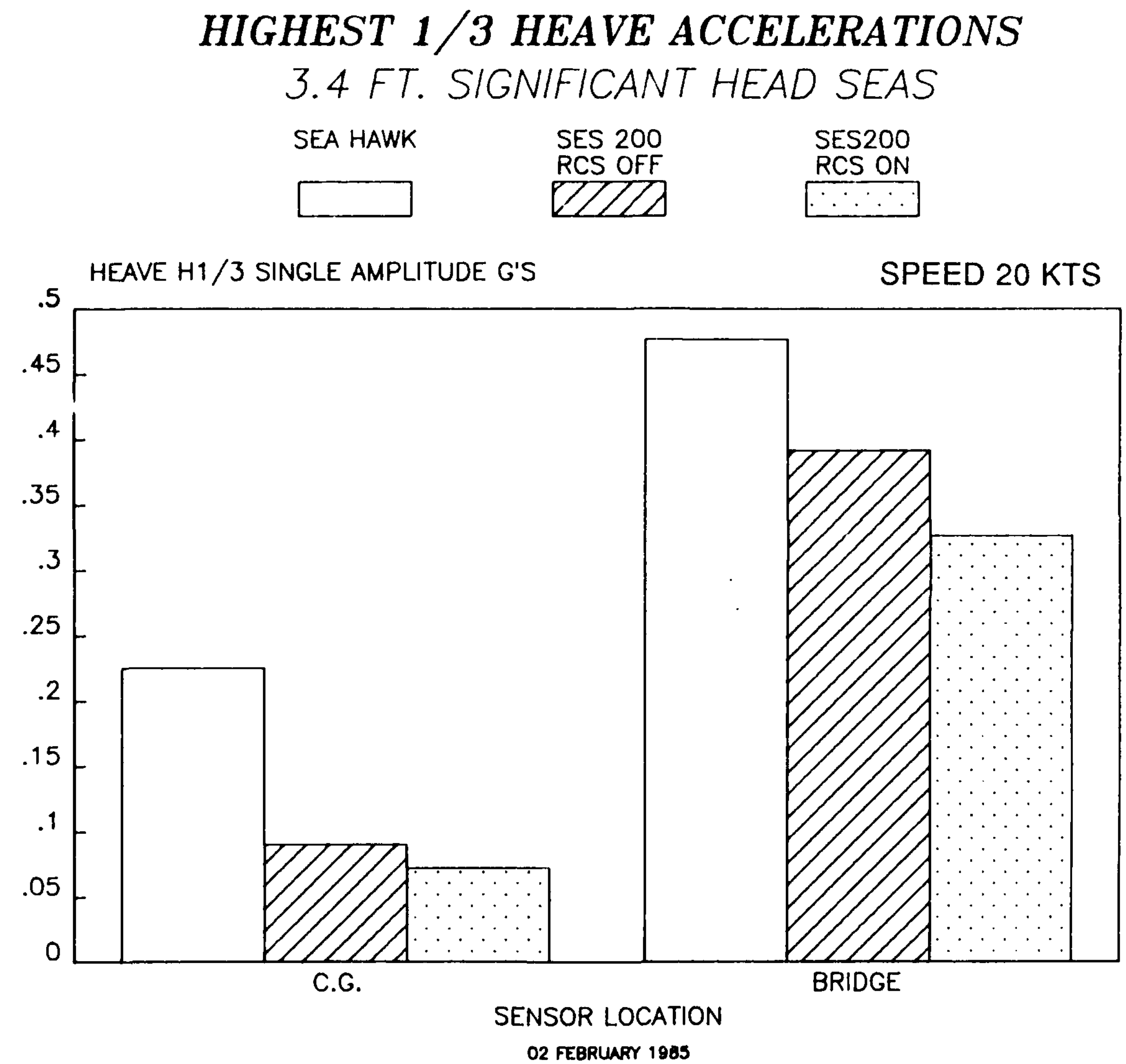


FIGURE 16. BRIDGE AND CG ACCELERATIONS COMPARED IN 3.4 FT. HEAD SEAS, 2 FEB 1985

is very often a subjective evaluation; however, it is quantifiable when using a standard scale which evaluates how ship motions and noise levels affect comfort. The two methods utilized have quite different standards and data analysis techniques. Despite this difference, both methods obtained similar levels of discomfort aboard the SEA HAWK. The two standards utilized were the International Organization for Standardization (ISO) No. 2631-178(E) and the National Aeronautics and Space Administration (NASA) algorithm, References 4 and 5 respectively. Both standards address the effect of high frequency vibrations above .5 Hz on subjects. This type of motion causes discomfort, and over a period of time, fatigue and decreased proficiency. The ride quality evaluation here does not address low frequency (.05 to .5 Hz) motions which typically cause motion sickness or seasickness. The SEA HAWK along with the SES-200 and other air cushion vehicles experience relatively high frequency (2 Hz) vertical accelerations which are related to air cushion dynamics. These motions are not usually experienced on conventional displacement vessels below moderate speeds (25 knots).

ISO Fatigue Standard

The ISO standard is based upon subjective tests of many subjects exposed to vertical accelerations at various frequencies while in the seated position. According to ISO, Reference 4, the four factors responsible for determining the human response to vibration are intensity, frequency, direction (vertical or horizontal), and duration (exposure time) of the vibration. The three quantifiable human responses to vibrations are the preservation of work efficiency, health or safety, and comfort.

The ISO fatigue-decreased proficiency boundary, Figure 17, specified a limit beyond which exposures to vibrations can be regarded as carrying a significant risk of impairing work effi-

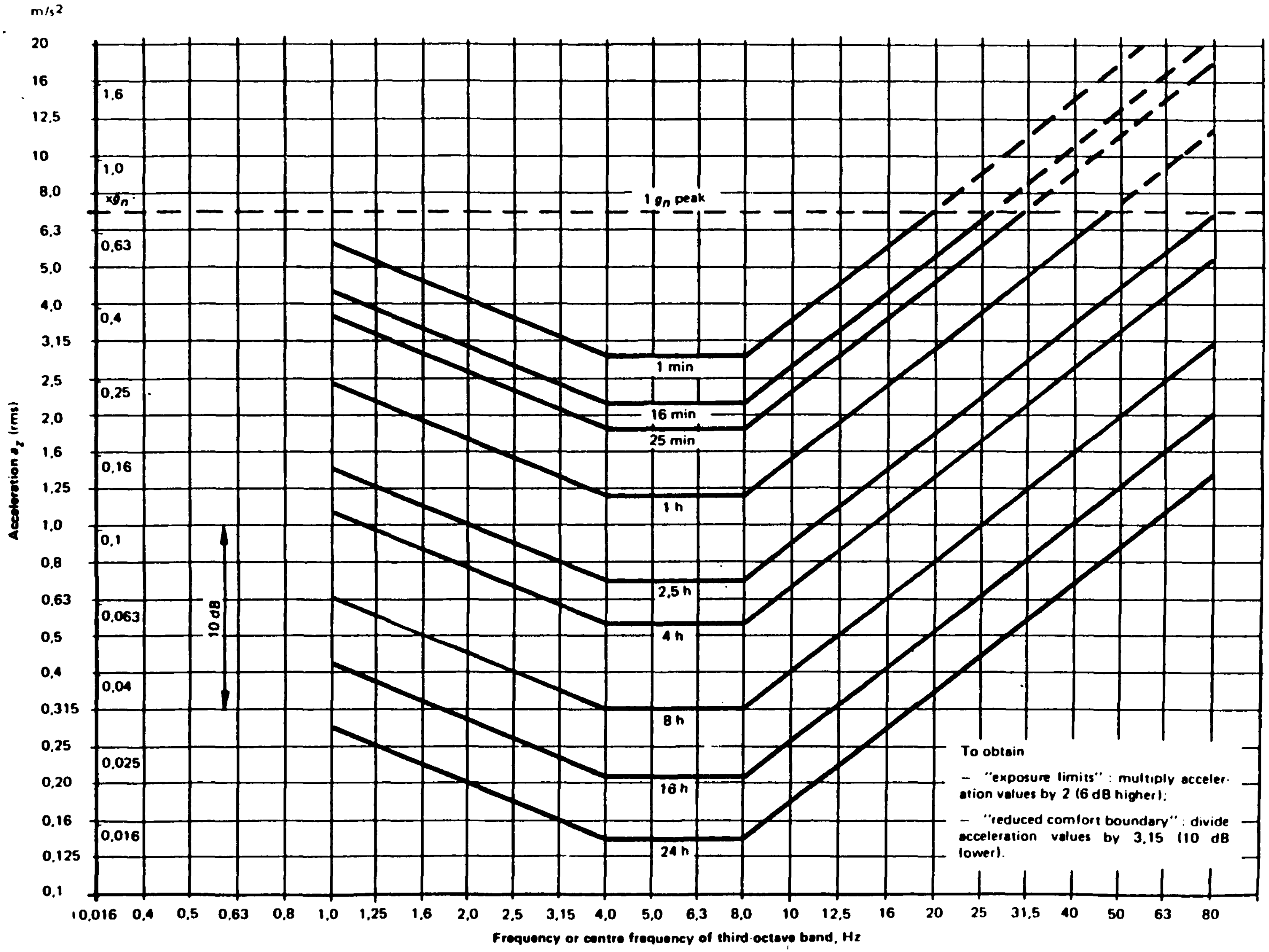


FIGURE 17. VERTICAL "LONGITUDINAL" ACCELERATION LIMITS AS A FUNCTION OF FREQUENCY AND EXPOSURE TIME

(From Reference 4)

ciency in many time-dependent tasks (such as watchstanding aboard ship). Although individuals may respond differently to vibrations, the fatigue limits showed the general level of onset of such degradation. The exposure limit for health or safety is similar to the fatigue decreased proficiency boundary but corresponds to acceleration levels two times (6 dB) higher. The exposure limit is defined as half the level considered to be the threshold of pain.

The Bruel and Kjaer (B&K) Human Response Vibration Meter Type 2512 was utilized to measure these fatigue limits using ISO weighting filters on the vertical acceleration signal. The unit displays the exposure limit, the equivalent continuous vibration level (Leq), and the maximum peak vibration level.

It is well known and documented that operation in increasingly higher sea states increases incidents of sea sickness caused by low frequency accelerations. This does not always hold true when evaluating human fatigue caused by high frequency vertical accelerations because short crested seas and the vessel's response to those wave encounters are the dominant factors. Fourteen measurements were taken during three days in sea conditions ranging from 2 to 6.4 foot significant seas. During two of those days (30 and 31 January 1985), concurrent measurements were made by NASA personnel using their own ride quality meter. All measurements were made in the starboard berthing area adjacent to the mess deck on the SEA HAWK. The B&K meter (ISO Standard) results are presented in Table III. Head sea runs in 4 to 5 foot seas are generally the most fatiguing. The wave period as well as height seems to have a dramatic effect on human fatigue on the SEA HAWK in head seas. Head seas runs on 31 January and 2 February in 4 foot seas resulted in quite different fatigue times in similar conditions. The time to reach 100% of the exposure limit was 4.5 hours on 2 February in 4.7 second period 3.9 foot waves, compared to 10.2 hours on 31 January in 6.2 second period 4 foot waves. The

TABLE III

SUMMARY OF HUMAN RESPONSE VIBRATION METER* MEASUREMENTS
ON CGC SEA HAWK STBD BERTHING AREA

DATE 1985	DISPLACEMENT LONG TONS	SPEED (KTS)	SIGNIFICANT SEAS (FT)	WAVE PERIOD	VESSEL HEADING	TIME TO REACH 100% FATIGUE DECREASED PROFICIENCY LIMIT (HRS)	TIME TO REACH 100% EXPOSURE LIMIT (HRS)	"Leq" AVERAGE WEIGHTED VERTICAL ACCELERATION (G's)	MAXIMUM PEAK VERTICAL ACCELERATIONS (G's)
30 JAN	143.5	20	2.0 Chop	3 sec.	Various	10.0	25.0	.031	.265
	(HEAVY)	20	2.0 Chop	"	Various	6.2	15.5	.038	.340
		20	2.5 Chop	"	Various	3.6	9.0	.051	.367
31 JAN	138.6	20	4.0	6.2 sec.	Head Seas	4.1	10.2	.051	.340
	(MEDIUM)	20	4.0	"	Bow Qtr.	4.1	10.2	.051	.330
		20	4.0	"	Beam	8.3	20.7	.036	.158
		20	4.5	"	Stern Qtr.	11.5	28.7	.025	.128
		20	4.5	"	Following	12.5	31.2	.024	.158
		20	6.4	"	Head	3.1	7.7	.064	.630
2 FEB	143.8	19	3.9	4.7 sec.	Head	1.8	4.5	.058	2.30
	(HEAVY)	19	3.9	"	Bow Qtr.	5.0	12.5	.046	0.36
		19	3.9	"	Beam	2.2	5.6	.054	1.70
		19	3.9	"	Stern Qtr.	4.8	25.0	.045	1.1
		19	3.9	"	Following	8.3	20.7	.035	0.97
					MEAN	6.1 HRS	16.1 HRS	.043 G's	.654

* Bruel & Kjaer Type 2512 Human Response Vibration Meter utilized, Whole Body 1-80 Hz range. Vertical accelerations were measured.

shorter period waves are causing larger heave accelerations at high frequencies because the encounter frequency in head seas is exciting the natural heave frequency of the vessel at 2 cycles per second. The head seas run in short crested 4 foot seas with a 4.7 second period was more fatiguing than the 6.4 foot head seas run in 6.2 second period waves. The time to reach 100% exposure limit in 6.4 foot seas was 7.7 hours compared to 4.5 hours in short crested 3.9 foot waves.

The mean time to reach 100% of the exposure limit for the three day testing was 16.1 hours. This is approximately the same level obtained in five previous test days conducted in 1983 and 1984 as documented in Reference 6. The mean time to reach 100% of the exposure limit was 15.1 hours during those previous tests conducted in 1-4 foot seas.

These ISO standards are time-dependent and relate mainly to fatigue caused by vertical accelerations. The NASA meter addresses a discomfort limit which is not time-dependent by using motions in five degrees of freedom as well as sound level effects.

<u>NASA Discomfort Standard</u>

The NASA Langley Research Center has developed a generalized ride comfort model for estimating passenger ride comfort in the presence of complex vehicle vibration and interior noise. As part of this research NASA has developed a portable, self-contained ride quality meter for use in obtaining real-time estimates of passenger ride comfort during actual vehicle operations. This meter is a direct hardware and software implementation of the generalized ride comfort model.

The NASA model was developed in a research program that obtained subjective ratings from more than 3000 persons who were exposed to controlled combinations of vehicle vibration and in-

terior noise using the NASA ride quality simulator. This research resulted in a model with the unique capability of transforming individual elements of the combined noise and vibration environment into subjective units and then summing the subjective units to produce a single discomfort index typifying passenger acceptance of the environment.

The ride quality meter contains a sensor package for simultaneously measuring five axes of vehicle vibration and a microphone for measuring interior vehicle noise. The vibration sensor package can be placed on the floor of a vehicle at a location selected by the user. At the selected location it will measure vehicle vibration (acceleration) in the vertical, lateral, longitudinal, roll, and pitch axes. Similarly, the microphone can be placed at a user selected location. Signals from the sensor package and microphone are fed to the ride quality meter which conditions and processes each one according to the NASA comfort algorithm. Meter output provides the user a number of options for use in assessing vehicle ride comfort as well as identifying particular contributing sources of passenger discomfort. These options include: total overall discomfort, vibration component of total discomfort, noise component of total discomfort, due to individual axes of vibration, discomfort due to individual octave bands of noise, and discomfort corrected for trip duration. These outputs are provided via an internal printer. The ride quality meter can be operated off of vehicle power when available or by use of rechargeable battery packs.

No other method is known to exist that can provide such detailed ride comfort information during actual vehicle operations. This meter provides the first known capability to directly sum the effects of noise and vibration into a single objective comfort index. The meter, in essence, acts as a reliable and accurate passenger jury.

Two NASA engineers from Langley Research Center, Hampton, VA conducted ride quality tests aboard the SEA HAWK on 30 and 31 January. Their findings were similar to the ISO method in that the ride of the SEA HAWK was above the discomfort level 53% of the time on 30 January in 2 foot chop and in the discomfort range 81% of the time on 31 January in 4 foot seas. The unique aspects of their results is that it identifies the primary factors contributing to that total discomfort index. A ride is considered uncomfortable if the total subjective discomfort level is above 2.5. The NASA algorithm was designed for comfort evaluations on vehicles and is valid for short term (less than two hour) rides. It is not intended to be a time-dependent measurement of fatigue effects which the ISO standards address. The NASA ride quality measurements on board the SEA HAWK are documented by the NASA preliminary information report (PIR) No. SD-5 attached as Appendix C to this report.

The NASA report identifies the major contributing factors to the discomfort index measured on the SEA HAWK. On both days, the highest discomfort levels were made during high speed runs while low measurements were obtained on "ride conditions" when the vessel was dead in the water. On 30 January in relatively low sea states (2 foot chop) the dominant contributor to vibration discomfort was roll axis vibration while vertical axis vibration generally was the second longest contributor followed by lateral accelerations.

During measurements in 4-6 foot seas taken on 31 January, the dominant contributor to vibration discomfort was vertical acceleration. Roll vibration discomfort varied slightly compared to 30 January tests while lateral vibration discomfort was similar both days. Sound levels contributed significantly to total discomfort on both test days. Noise contribution to total discomfort depends upon the level of ship vibration which is simultaneously present. To improve ride quality requires mea-

sures taken to control noise transmission into living spaces as well as reduction of ship vibration.

SES-200 Ride Control System Evaluation

The SES-200 ride control system (RCS) is a prototype unit built by Maritime Dynamics, Inc. for the Navy. The purpose of the RCS on the vessel is to modulate cushion airflow to smooth out cushion pressure and thus reduce vertical acceleration. The system uses one to four pressure signals for control law feedback. A microprocessor manipulates the data using an algorithm to output a single control signal to the four vent valves. The four vent valves are located on the main deck centerline as seen in Figure 12. The effective open area of the four vent valves is 9 square feet each. A set of louvered valves allows the ship's air cushion to be vented vertically in order to minimize pressure changes caused by passing waves and cushion venting. This system is designed to attenuate high frequency whole body vibrations in the 1 to 4 Hz range which causes crew fatigue. The low frequency (.05 to .6 Hz) ship motions caused by encountering swells are not attenuated because the motion is related to hull interactions with the waves not air cushion dynamics. These low frequency motions which are not affected by the RCS typically cause seasickness.

The SES-200, as well as the 110' Coast Guard SES's, have a relatively high resonant or natural heave frequency at approximately 2 Hz which is a major contributor to vertical accelerations in calm water to 4 foot seas. These high frequency heave motions are most pronounced in high speed runs in head and bow quarter seas. As demonstrated in Reference 6, this high frequency energy is most pronounced on a 110' Coast Guard SES at speeds above hump speed (22 knots). The SEA HAWK could not attain speeds above 22 knots during these tests. The SES-200 was tested below its primary hump speed which exists in the 30+ knot range and could not attain speeds above 23 knots during these tests. With the higher length to beam ratio, the

SES-200 is not designed to operate above its hump speed.

When seas get larger, above 4 feet, and wave periods get longer, the wave encounter frequencies (.05 to .6 Hz) become the major contributor to vertical accelerations and thus the ride control system is less effective because it is not designed to control these low frequency ship motions. As sea states increase above five feet, waves start to slam the wet deck area of the hull. Voluntary speed reduction usually occurs when slamming starts.

In order to evaluate the RCS on the SES-200 during on-cushion operations, the system was turned on and then off for half of each 30 minute seakeeping leg conducted side-by-side the USCGC SEA HAWK on four separate days. Headings relative to the waves were varied from head to following seas in 45 degree increments. In addition to these side-by-side runs at different orientations to the major seas, one period of time on 31 January was devoted to the Navy for 12 independent runs to evaluate the RCS. The Coast Guard test team recorded and analyzed ship motions during all testing aboard the Navy SES-200.

Most of the seakeeping tests were conducted in sea state III (3.0 to 5.7 foot significant wave heights). One test set for the Navy was conducted in sea state IV with 6.4 foot significant waves. A calm water evaluation was also conducted for head seas runs only, in 2.2 foot waves. All seakeeping data collected is presented in Appendix B, Tables B-XI to B-VIII. The wave field directional data and PSD plots collected during seakeeping tests are presented in Figures B-XIX to B-XXVIII.

Based on previous evaluations conducted by the Navy and the company which designed the RCS (Maritime Dynamics, Inc.) documented in Reference 3, we were anticipating a 30% attenuation of vertical accelerations at the center of gravity (cg) due to the RCS in sea state III tests. While proceeding at

18 to 20 knots, the RCS attenuated vertical accelerations at the cg to varying degrees over the four seakeeping test days. One day, 31 January, the RCS failed to attenuate accelerations in 4 foot and 6 foot head and bow quarter seas. On two other days the system attenuated vertical accelerations at the cg 36% on 27 February in 3.7 foot head seas and attenuated accelerations 20% on 2 February in 4 foot head seas. Occasionally, the RCS caused an amplification of vertical accelerations.

A summary of RCS performance is presented in Table IV. It can be seen from this data table that the ride control system performed intermittently. The Coast Guard test team director noted that on 31 January a control card used in the RCS electronics package had malfunctioned and the Maritime Dynamics, Inc. representative made attempts to compensate for that component failure. The RCS did not attenuate acceleration that day. It was also noted that the partly opened (bias) setting of the vent valves was about 30% on the first test day (27 January) and each day thereafter the valves had decreased bias opening. During the last seakeeping day (2 February), the bias of the vent valves were closed except for venting actions. The RCS is most effective when there is a significant bias open setting on the vent valves. This allows for control of the wet deck cushion pressure to reduce positive pressure spikes as well as reducing low pressure troughs. With no bias opening, the system can only control pressure in one direction (positive spikes).

The RCS is designed to attenuate relatively high frequency 1 to 4 Hz vertical accelerations of the ship by controlling air cushion pressure. It cannot affect low frequency .05 to .6 Hz motions caused by wave encounters on the hull. The RCS is thus most effective in low to moderate short crested seas (2 to 4 feet significant seas) where a good part of the energy contributing to vertical accelerations is at the natural heave frequency response of the vessel at 2 Hz. As the sea states increase above four feet, the major energy contributing to

TABLE IV

RCS EFFECTIVENESS ON THE SES-200

DATE 1985 (SPEED)	RELATIVE HEADING TO THE SEAS	ATTENUATION OF VERTICAL ACCELERATIONS: CENTER OF GRAVITY: ATTENU-ATION	CENTER OF GRAVITY: REFERENCE H 1/3 ACCEL. RCS OFF (G's)	BRIDGE: ATTENU-ATION	BRIDGE: REFERENCE H 1/3 ACCEL. RCS OFF (G's)	SEA STATE/ WAVE HEIGHT
27 JAN (18kts)	HEAD BOW QTR. STERN QTR.	36% 7% 7%	.153 .061 .077	n/a n/a n/a	n/a n/a n/a	III 3.7 ft. significant waves
28 JAN (20 kts)	HEAD	-12%	.032	0	.461	II 2.2 Ft. significant waves
31 JAN 0900 (20kts)	HEAD BOW QTR. BEAM STERN QTR.	-2.5% -16% 37% 21%	.121 .119 .099 .046	1% 2% 1.5% 0.5%	.438 .446 .439 .437	III 4.0 ft. significant waves
31 JAN 1600 (20kts)	HEAD BOW QTR. BEAM STERN QTR. FOLLOWING	2% 0 38% 21% -134%	.116 .103 .118 .053 .036	0 0 -5% 0 0	.435 .434 .425 .437 .440	IV 6.4 ft. significant waves
2 FEB (20kts)	HEAD BOW QTR. BEAM STERN QTR. FOLLOWING	20% 16% 56% 2% -20	.09 .084 .071 .074 .024	17% 18% n/a 14% 16%	.391 .309 n/a .422 .242	III 3.9 ft. significant waves

-% Attenuation indicates the amount accelerations were amplified when the RCS was turned on compared to levels with the RCS off.

n/a - Data Not Available

vertical accelerations is at the low frequency hull encounters with the swells. For this reason, the RCS is not effective in attenuating vertical accelerations in high sea states.

The effectiveness of the RCS and its limitations can be seen by looking at a vertical acceleration signal in the frequency domain. In this way, the heave power which is attenuated can be seen and evaluated. The most dramatic effect of heave power attenuation at the cg can be seen during a head seas run on 2 February at 19 knots in 3.9 foot seas, Figure 18. The majority of power attenuated is centered around 2 Hz, the natural heave frequency of the vessel. Note that there is some power attenuated as low as .5 Hz, however, no power is attenuated in the wave encounter low frequencies centered around .25 Hz (4 second period). Heave power is larger on the bridge compared to the cg because of the additional acceleration caused by the pitch action of the vessel, Figure 19. The power centered at .25 Hz, the wave encounter frequency, has increased the most on the bridge compared to the 2 Hz power. The RCS still reduces the higher frequency heave power; however, there is a smaller percent reduction in total heave power on the bridge. This is because the low frequency motion which is not affected by the RCS is more pronounced due to pitch action experienced on the bridge centered at a pivot point close to the center of gravity.

During runs in 6.4 foot significant seas, the major power was at 0.3 Hz (3.3 second encounter period). There is little room for RCS effectiveness in this case, as seen in Figure 20. This is because very little heave power was present between 1 and 3 Hz to be attenuated by the RCS. This plot dramatically demonstrates that in rough seas (6.4 foot), the RCS is not effective on the SES-200.

Recent R&D Center tests conducted in February 1986 on the air cushion pressure and fan system of the CGC SHEARWATER

SES-200
2 FEBRUARY 1985
HEAVE PSD AT CG
SPEED 19 KTS - HEAD SEAS
3.9 FT SIGNIFICANT SEAS

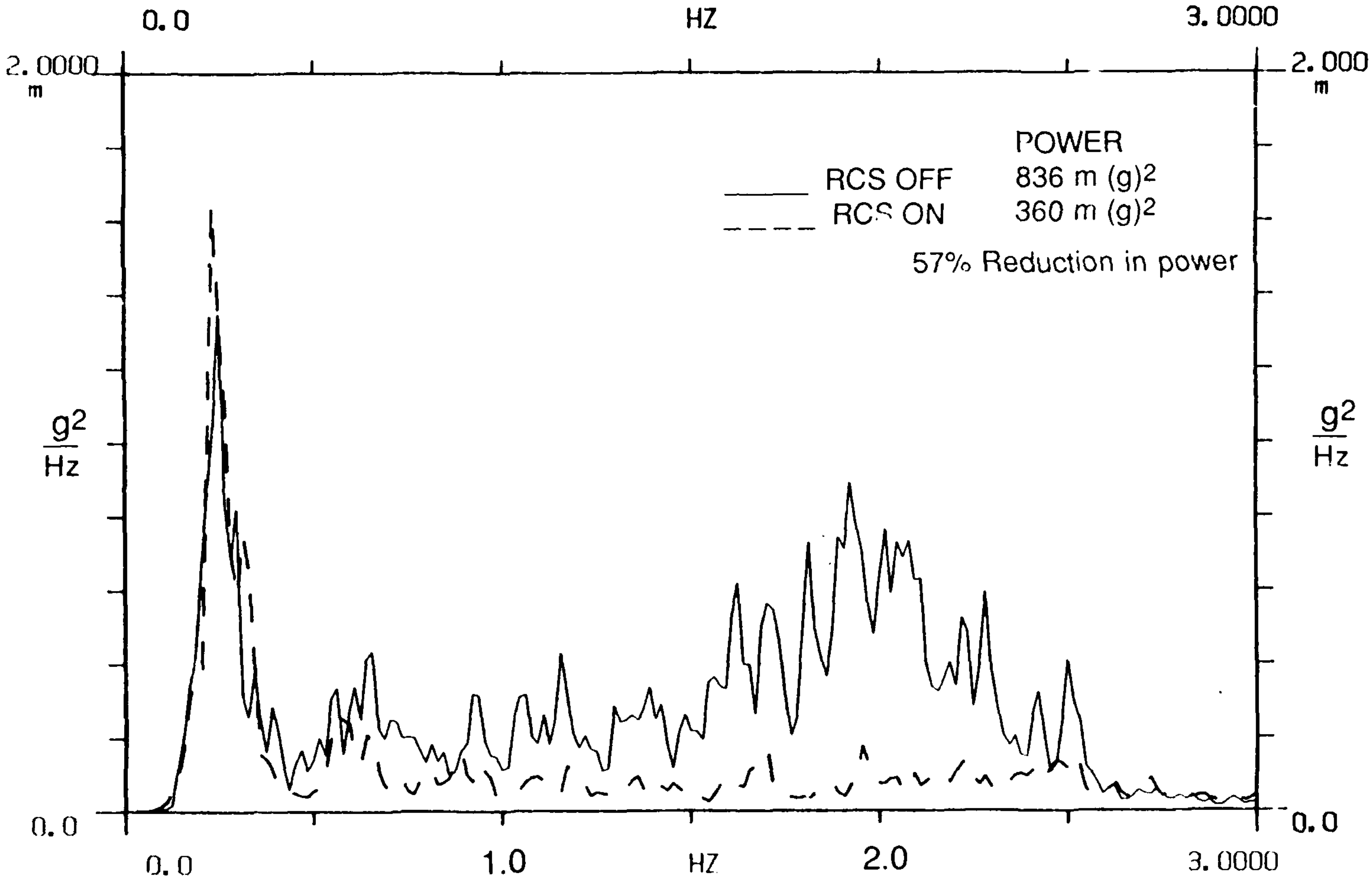


FIGURE 18. SES-200 RCS EFFECT ON HEAVE SPECTRUM AT CG IN 3.9 FT. SEAS

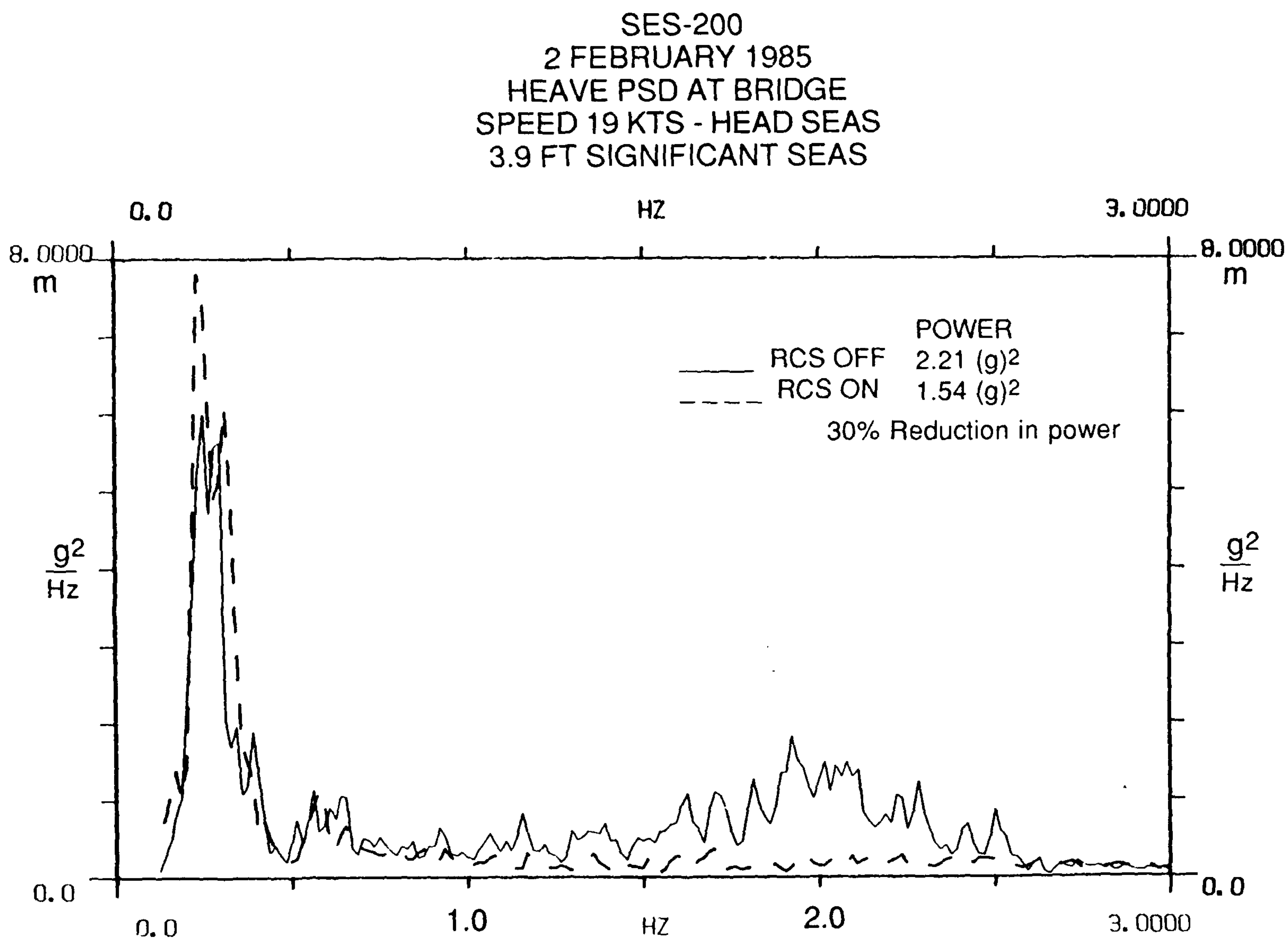


FIGURE 19. SES-200 RCS EFFECT ON HEAVE SPECTRUM AT BRIDGE IN 3.9 FT. SEAS

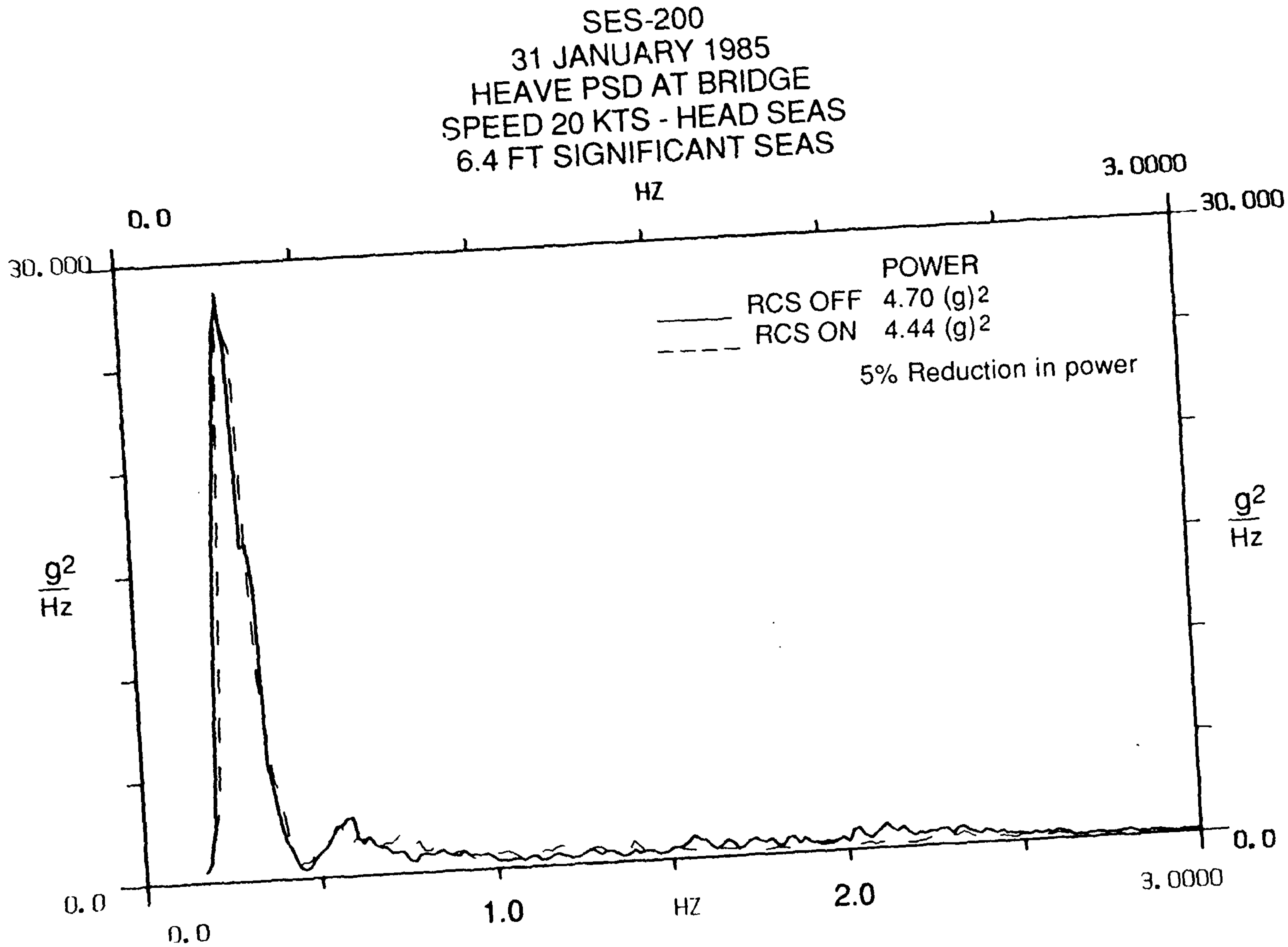


FIGURE 20. SES-200 RCS EFFECT ON HEAVE SPECTRUM AT BRIDGE IN 6.4 FT. SEAS

(WSES-3) show that air flow was lower than expected and cushion pressure control by lift engine rpm changes was marginal because the fans are operating in a stall region. Addition of an RCS will add a parallel flow out of the wet deck. Through control of the bias opening of the vent valves that parallel air flow may change the air system's resistance enough to get the fans operating in a stable region. This would improve the ride quality and possibly improve fan efficiency.

SUMMARY

The 160' U.S. Navy SES-200 has many advantages over the 110' U.S. Coast Guard SES. These SES-200 advantages all relate to the increased length, displacement and payload benefits when compared to the smaller CGC SEA HAWK. The SES-200 has lower wave making drag, better seakeeping and longer range, with essentially the same speed and fuel efficiency characteristics of the CGC SEA HAWK. The SES-200 has more than twice the range of the SEA HAWK. Despite a 25% larger displacement, the SES-200, with essentially the same power plant configuration, has slightly less fuel consumption than the SEA HAWK at 22 knots. This seemingly contrary relationship is possible because the additional 50 foot length of the SES-200 reduces wave making drag of the vessel. Both vessels have fairly flat fuel efficiency curves which indicate that routine full speed operation is an effective operating profile for these surface effect ships.

The liabilities of the SES-200 are that turning diameters are twice as large as the SEA HAWK and thus has slower turning rates. The SES-200 has four lift engines and fans in order to maintain proper cushion pressure and air flow compared to two fans on the CGC SEA HAWK. Both vessels have marginal noise levels in living compartments at moderate and fast speeds.

The seakeeping characteristics of the SES-200 without ride

control are better than the SEA HAWK with the exception of surge acceleration. Surge accelerations on the SES-200 in head and bow quarter seas are of the same order of magnitude as the vertical accelerations at the cg. This translates to walking tasks being more difficult on the SES-200 compared to the SEA HAWK as reported by test team members. Surge acceleration on the SEA HAWK are one order of magnitude below its heave accelerations at its cg.

Roll and pitch amplitudes on both vessels are very low and are considered very good. Vertical accelerations at the cg of the SES-200 with the ride control system off are approximately 70% lower than those encountered on the SEA HAWK. That benefit, however, is mitigated to some extent on the bridge of the SES-200 because it is further forward of its cg compared to the bridge location on the SEA HAWK. Vertical accelerations on the SES-200 bridge is dropped down to approximately 33% below those experienced on the bridge of the SEA HAWK.

The ride control system on the SES-200 intermittently attenuated vertical accelerations during the two week test period. On one seakeeping day it did not function and it occasionally amplified accelerations. When it was operational it attenuated vertical accelerations 20 to 36% in sea state III (4 ft.) head seas at the cg and 17% on the bridge while proceeding at 20 knots. The ride control system (RCS) does not attenuate low frequency wave encounters and so it is not effective in sea states IV (6 ft.) and above where those low frequency motions dominate. The RCS reduces the high frequency (2 Hz) vertical accelerations which are responsible for fatigue effects on crew members. The RCS is most effective in head and bow quarter moderate seas of 2-4 feet in height.

Ride quality was evaluated on the SEA HAWK. According to ISO standards, high frequency vertical accelerations cause human fatigue and decreased proficiency within 16 hours underway

in sea state III (4 foot waves). The NASA ride quality meter substantiated the vertical accelerations are the major contributor to ride discomfort and that noise levels added to that discomfort level.

UPDATE

Many power plant performance improvements have been completed on the three Coast Guard SESs since these tests were completed on the USCGC SEA HAWK in February 1985. As of July 1987, all three 110' SEA BIRD class SESs were routinely attaining a design speed of 28 to 30 knots at full displacement in sea state 2, (Reference 7). Total fuel consumption (main engines, lift engines and generator) at this speed is 180 gallons per hour. This improved speed and fuel consumption performance is attributed to:

a. decreasing propeller pitch from 49" to 46", now enabling the vessels to easily transit hump speed in higher sea states. The SEA HAWK engines were load limited by the 49" pitch propeller as tested in 1985 at 22 knots. The main engines are now RPM limited at 1900 RPM (voluntarily) at 30 knots.

b. main engine modifications made in February 1986 to increase horsepower by 200 HP on each engine. Consistent top speed performance, however, was not obtained until propeller pitch was reduced.

c. main engine intake fuel temperature being reduced from worse case conditions of 145°F to 95°F through installation of fuel coolers (heat exchangers). Exhaust system back pressure was relieved when an original piping system problem was discovered. Lift fan efficiency was improved through replacement of smaller profile intake screens on the SEA HAWK only. Installation of turning vanes below the fans improved flow to ducts which supply air to the seals. Stern seals are now trimmed to fit each vessel to prevent material folding which allowed undesired pressure loss. Forced air ventilation to engine room was improved dropping air temperature by 30°F to an average of 105°F-110°F.

In September of 1988, the Coast Guard Research and Development Center tested the USCGC SEA HAWK (WSES-2) to analyze the Ride Control System (RCS) that was installed on the ship. The data were obtained in 3 foot and 6 foot significant seas during a normal patrol operation. The following information is provided as the RCS is reflective of an improvement of this class of vessels. It should be noted that only the USCGC SEA HAWK is currently configured with the RCS.

Tests indicate that there is little variation in roll and pitch either in "angle" or "rate" with the RCS <u>on</u> or <u>off</u>. There is, however, significant reduction in heave at the Center of Gravity (CG) and the Wheelhouse with the RCS on versus off. The difference is as shown in Table V, and Figures 21 and 22.

Analysis of the three foot seakeeping data show that normally there is an amplification of approximately 1.15 - 1.20 on vertical heave values between the CG and the Wheelhouse. This is true because the Wheelhouse is located approximately six feet forward of the CG sensing point. Visual observations of the USCGC SEA HAWK in motion indicate that the center of rotation is located 33 feet (10.1 meters) aft of the CG.

	Location	
Seas	CG	Wheelhouse
HEAD	-20%	-24%
BOW	-30%	-29%
BEAM	-35%	-30%
QTR	-26%	-20%
FOLLOWING	-16%	-15%

Table V: RCS Heave Reduction

Table VI shows the engineering data for the three wave height

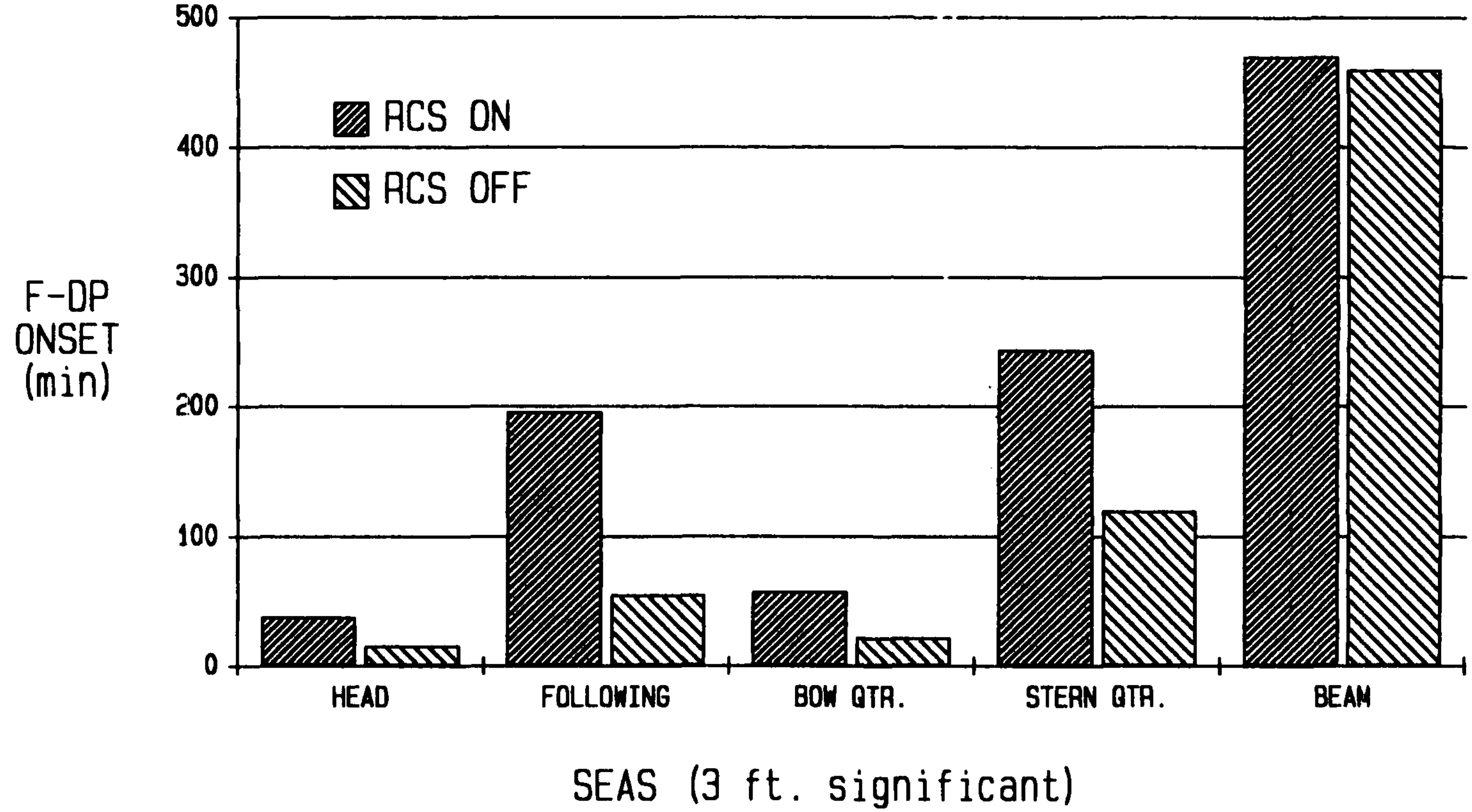


FIGURE 21: EXPOSURE LIMITS RCS ON vs RCS OFF

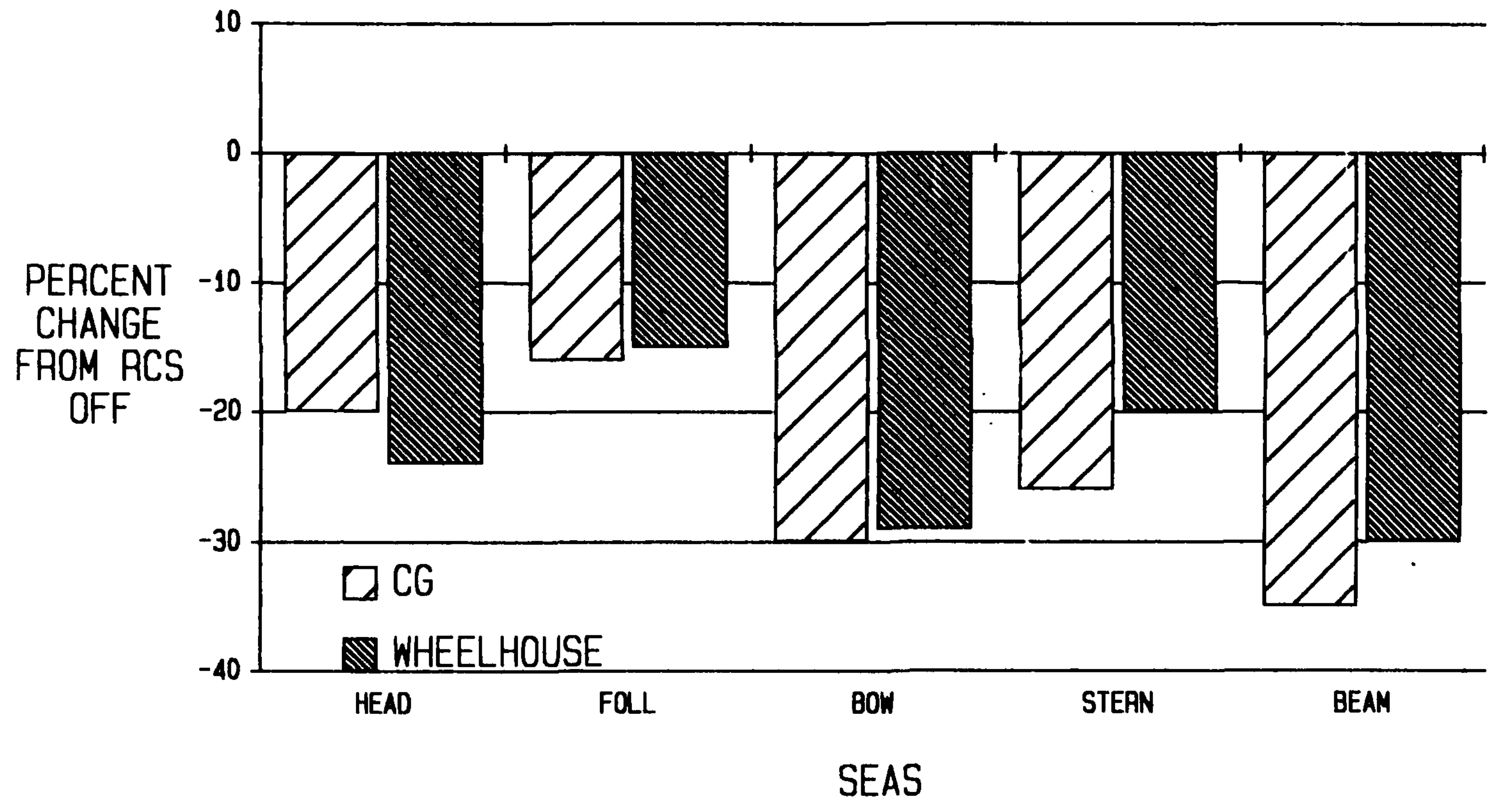


FIGURE 22: VERTICAL HEAVE; RCS ON

Table VI. USCGC SEA HAWK Seakeeping Data (3 foot seas)

Relative Sea Direction	Averaging Type	Roll Angle (deg) OFF	Roll Angle (deg) ON	Pitch Angle (deg) OFF	Pitch Angle (deg) ON	Roll Rate (deg/sec) OFF	Roll Rate (deg/sec) ON	Pitch Rate (deg/sec) OFF	Pitch Rate (deg/sec) ON	Acceleration (G's) Heave (Bridge) OFF	Acceleration (G's) Heave (Bridge) ON	Acceleration (G's) Heave (CG) OFF	Acceleration (G's) Heave (CG) ON	Acceleration (G's) Surge (CG) OFF	Acceleration (G's) Surge (CG) ON	Acceleration (G's) Sway (CG) OFF	Acceleration (G's) Sway (CG) ON
HEAD	1/10	0.896	0.894	0.418	0.462	1.385	1.257	1.011	1.058	0.290	0.235	0.276	0.227	0.030	0.028	0.027	0.030
	1/3	0.726	0.732	0.333	0.344	1.077	0.961	0.787	0.813	0.222	0.174	0.208	0.169	0.023	0.022	0.021	0.023
	RMS	0.512	0.522	0.241	0.246	0.732	0.640	0.551	0.573	0.155	0.121	0.146	0.118	0.016	0.016	0.015	0.016
	MEAN	0.453	0.472	0.221	0.220	0.620	0.534	0.486	0.503	0.135	0.103	0.125	0.102	0.014	0.014	0.014	0.015
	HIGH	1.178	1.208	0.633	0.819	2.014	1.878	1.942	2.055	0.513	0.462	0.503	0.361	0.045	0.045	0.042	0.081
BOW QUARTER	1/10	0.862	1.038	0.484	0.454	1.258	1.471	1.119	1.069	0.273	0.197	0.261	0.186	0.025	0.025	0.031	0.033
	1/3	0.686	0.772	0.364	0.352	0.951	1.127	0.852	0.824	0.205	0.146	0.193	0.135	0.020	0.019	0.023	0.025
	RMS	0.485	0.542	0.254	0.255	0.638	0.772	0.593	0.572	0.142	0.101	0.135	0.094	0.014	0.014	0.015	0.016
	MEAN	0.431	0.474	0.226	0.232	0.536	0.655	0.516	0.498	0.122	0.086	0.115	0.080	0.013	0.013	0.015	0.016
	HIGH	1.225	1.555	0.735	0.654	1.869	2.693	2.295	1.951	0.506	0.421	0.516	0.442	0.037	0.038	0.058	0.049
BEAM	1/10	3.776	3.719	0.815	0.688	5.140	4.952	1.403	1.232	0.202	0.140	0.206	0.133	0.027	0.027	0.042	0.040
	1/3	3.034	2.990	0.642	0.519	3.797	3.726	1.070	0.920	0.147	0.101	0.148	0.094	0.021	0.020	0.032	0.031
	RMS	2.185	2.115	0.436	0.355	2.611	2.536	0.724	0.628	0.102	0.071	0.101	0.066	0.015	0.014	0.022	0.021
	MEAN	1.958	1.870	0.374	0.306	2.161	2.104	0.615	0.532	0.087	0.061	0.085	0.056	0.013	0.013	0.019	0.018
	HIGH	5.119	4.650	1.153	1.019	8.236	6.553	1.894	2.119	0.453	0.292	0.366	0.255	0.038	0.040	0.080	0.058
STERN QUARTER	1/10	1.891	1.659	0.940	0.833	1.731	1.549	1.334	1.304	0.138	0.110	0.117	0.089	0.028	0.027	0.032	0.029
	1/3	1.496	1.275	0.738	0.670	1.310	1.153	0.965	0.932	0.107	0.083	0.090	0.067	0.022	0.027	0.024	0.022
	RMS	1.029	0.875	0.516	0.461	0.870	0.764	0.652	0.631	0.074	0.059	0.064	0.047	0.015	0.015	0.017	0.016
	MEAN	0.891	0.752	0.452	0.402	0.706	0.621	0.542	0.542	0.065	0.051	0.056	0.042	0.014	0.013	0.015	0.014
	HIGH	2.615	2.142	1.270	1.268	2.447	2.450	2.405	2.117	0.219	0.214	0.218	0.168	0.075	0.048	0.050	0.045
FOLLOWING	1/10	1.056	1.292	0.697	0.736	1.364	1.261	1.301	1.289	0.126	0.110	0.104	0.090	0.031	0.030	0.028	0.029
	1/3	0.839	1.009	0.561	0.576	1.056	0.971	0.975	0.968	0.096	0.082	0.080	0.067	0.024	0.023	0.022	0.022
	RMS	0.603	0.715	0.396	0.394	0.718	0.647	0.660	0.658	0.067	0.057	0.057	0.043	0.017	0.016	0.015	0.014
	MEAN	0.537	0.632	0.355	0.342	0.603	0.539	0.557	0.555	0.059	0.050	0.050	0.042	0.015	0.015	0.014	0.014
	HIGH	1.774	1.915	0.956	1.009	2.107	1.856	2.056	2.117	0.251	0.199	0.217	0.170	0.045	0.045	0.046	0.047

seakeeping test. The table shows the average of the largest H $^{1}/_{10}$, H $^{1}/_{3}$, RMS, mean and highest value recorded for all runs in head, bow quarter, beam, stern quarter and following seas.

Table VII shows the engineering data for the six foot seakeeping tests. Due to the heavy sea conditions, all runs were not completed as noted in the data tables. The seakeeping analysis shows that the six to seven foot (1.8 to 2.1 meter) significant wave height is the point at which the RCS stops being effective in reducing ship motion. At this point, the motion of the ship becomes great enough that the bow seals break contact with the water, causing the boat to lose cushion and slam down into the waves with personnel on board leaving their feet [8].

Table VII. USCGC SEA HAWK Seakeeping Data (6 foot seas)

Relative Sea Direction	Averaging Type	Roll Angle (deg) OFF	Roll Angle (deg) ON	Pitch Angle (deg) OFF	Pitch Angle (deg) ON	Roll Rate (deg/sec) OFF	Roll Rate (deg/sec) ON	Pitch Rate (deg/sec) OFF	Pitch Rate (deg/sec) ON	Acceleration (G's) Heave (Bridge) OFF	Heave (Bridge) ON	Heave (CG) OFF	Heave (CG) ON	Surge (CG) OFF	Surge (CG) ON	Sway (CG) OFF	Sway (CG) ON
HEAD	1/10	8.774	8.578	3.694	2.735	6.546	6.781	8.375	7.608	0.363	0.274	0.398	0.367	0.073	0.072	0.083	0.090
	1/3	6.351	7.034	2.776	1.837	4.470	5.345	6.085	5.773	0.246	0.183	0.282	0.245	0.053	0.056	0.059	0.064
	RMS	4.404	4.980	1.922	1.274	3.048	3.583	4.237	4.039	0.174	0.126	0.191	0.147	0.037	0.038	0.040	0.042
	MEAN	3.765	4.400	1.673	1.036	2.423	2.993	3.494	3.432	0.134	0.098	0.153	0.134	0.031	0.033	0.032	0.034
	HIGH	12.368	10.280	4.384	3.999	10.093	7.989	18.422	11.581	0.433	0.735	0.891	0.585	0.153	0.093	0.206	0.118
BOW QUARTER	1/10	2.257	7.116	2.096	3.299	5.337	5.248	8.285	8.009	0.326	0.303	0.425	0.447	0.068	0.071	0.063	0.069
	1/3	5.837	5.731	1.590	2.485	4.081	4.051	6.285	6.360	0.218	0.195	0.291	0.309	0.490	0.052	0.048	0.052
	RMS	4.191	3.641	1.110	1.751	2.851	2.768	4.385	4.429	0.151	0.136	0.196	0.209	0.034	0.035	0.032	0.035
	MEAN	3.792	3.025	0.960	1.503	2.457	2.343	3.726	3.804	0.119	0.102	0.154	0.159	0.028	0.030	0.027	0.029
	HIGH	9.750	11.279	2.858	3.695	7.668	7.208	11.617	10.301	0.886	0.677	0.830	0.612	0.103	0.109	0.107	0.110
BEAM	1/10	N.A.	7.753	N.A.	4.963	N.A.	9.853	N.A.	8.481	N.A.	0.259	N.A.	0.445	N.A.	0.082	N.A.	0.118
	1/3	N.A.	6.022	N.A.	3.622	N.A.	7.593	N.A.	7.133	N.A.	0.173	N.A.	0.322	N.A.	0.039	N.A.	0.083
	RMS	N.A.	4.175	N.A.	2.528	N.A.	5.059	N.A.	5.125	N.A.	0.117	N.A.	0.214	N.A.	0.040	N.A.	0.054
	MEAN	N.A.	3.606	N.A.	2.167	N.A.	4.128	N.A.	4.607	N.A.	0.089	N.A.	0.171	N.A.	0.033	N.A.	0.042
	HIGH	N.A.	10.535	N.A.	5.887	N.A.	11.914	N.A.	9.572	N.A.	0.582	N.A.	0.529	N.A.	0.136	N.A.	0.198
STERN QUARTER	1/10	7.105	7.042	1.832	1.643	7.914	8.625	2.497	3.354	0.048	0.122	0.194	0.220	0.048	0.043	0.087	0.095
	1/3	5.113	5.835	1.404	1.407	6.911	6.783	1.876	2.608	0.036	0.087	0.130	0.160	0.036	0.032	0.063	0.072
	RMS	3.921	4.138	0.971	0.993	3.916	4.695	1.220	1.738	0.024	0.059	0.087	0.108	0.024	0.022	0.041	0.049
	MEAN	3.384	3.715	0.833	0.854	3.141	4.021	0.955	1.401	0.020	0.040	0.069	0.087	0.020	0.019	0.032	0.041
	HIGH	11.202	8.831	2.631	1.875	10.082	11.766	11.766	5.121	0.066	0.255	0.419	0.390	0.066	0.054	0.013	0.132
FOLLOWING	1/10	N.A.	4.145	N.A.	N.A.	N.A.	2.923	N.A.	2.934	N.A.	0.114	N.A.	0.115	N.A.	0.053	N.A.	0.045
	1/3	N.A.	3.315	N.A.	N.A.	N.A.	2.177	N.A.	2.226	N.A.	0.086	N.A.	0.086	N.A.	0.036	N.A.	0.031
	RMS	N.A.	2.245	N.A.	N.A.	N.A.	1.462	N.A.	1.467	N.A.	0.059	N.A.	0.059	N.A.	0.026	N.A.	0.021
	MEAN	N.A.	1.903	N.A.	N.A.	N.A.	1.182	N.A.	1.171	N.A.	0.051	N.A.	0.051	N.A.	0.019	N.A.	0.018
	HIGH	N.A.	4.637	N.A.	N.A.	N.A.	4.292	N.A.	3.725	N.A.	0.223	N.A.	0.183	N.A.	0.080	N.A.	0.072

NOTE: N.A. = Not Available

RECOMMENDATIONS

Consideration should be given to reducing noise transmission from the engine room to the aft berthing compartment on the CGC SEA HAWK and the other two Coast Guard SESs. Presently, ISO duration time is exceeded after 13 hours exposure in aft berthing while proceeding at 20 knots. Although this is within acceptable limits, it is a marginal condition.

This technical evaluation and other tests conducted by the Coast Guard on the SES Sea Bird Class indicate that a ride control system is necessary in order to improve ride quality, reduce human fatigue and possibly extend the life of the hull and the lift system. Experience gained by retrofitting the Navy SES-200 and Coast Guard Cutter SEA HAWK with active ride control systems (RCS) demonstrate that it is difficult and expensive to accomplish after the ship is designed and built. Future procurements of SESs should include some form of an RCS as a standard design requirement.

The air cushion itself must be considered as an integral system of the ship rather than an isolated element in order to design, operate and maintain an efficient air cushion vehicle. The SES exhibits a 2-3 Hz bounce caused by the compressibility and resiliency of the air cushion itself even in calm water operations. This cushion instability measured on the SEA HAWK varied from 72 to 128 PSF. The lift fans, ducting system, seals, RCS, cushion volume, required flow rate, and pressure must be properly matched as a system to insure stable, steady state operation. Once a stable cushion is obtained, the immediate benefits are improved ride quality, less human fatigue, and a more efficient lift and propulsion system. The long-term benefits obtained by reducing high frequency whole ship oscillations are an extended hull life through the reduction in hull cracking and reduced maintenance on fans and seals.

ACKNOWLEDGEMENTS

I wish to acknowledge the superior effort and thoroughness in which Mr. Robert Desruisseau reduced the vast majority of the seakeeping data presented in this report. Many data sets were evaluated twice to ensure data integrity. He performed valuable data editing and some plotting functions as well which enhanced the quality of this report.

Mr. James Bellemare did an outstanding job as test director of the SES-200. This effort involved a great deal of technical expertise and test team coordination between the two vessels, which Mr.Bellemare handled admirably well. He was very helpful in conducting a technical review of this report.

The cooperation of the U.S. Coast Guard SES Division, U.S. Navy, and the officers and crews of both vessels enabled this test series to be completed successfully one week earlier than planned.

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APPENDIX A

DESCRIPTION OF INSTRUMENTATION

APPENDIX A

DESCRIPTION OF INSTRUMENTATION

EQUIPMENT	DESCRIPTION
SHIP MOTION PACKAGES (2) HUMPHREY, Inc.	This unit consists of a vertical gyro, a vertically stabilized three-axis accelerometer assembly, a directional gyroscope, a three-axis rate gyro assembly and all necessary power supplies and power switching relays. Nine outputs are available at ± 1 or ± 5 volts full scale with or without a 10 Hz low pass filter. Full-scale outputs can be varied as the table below indicates.
Pitch Angles	± 45°, 25° or 10°
Roll Angles	± 45°, 25° or 10°
Yaw Angles	± 175°
Pitch and Roll Rate	60, 30 or 10 deg/sec
Yaw Rate	30, 10 or 5 deg/sec
Surge & Sway Acceleration	± 1.0 or 0.5 G's
Heave Acceleration	± 2.0 or 0.5 G's
STORE 14D ANALOG TAPE RECORDER Lockheed Electronics Company	This analog tape recorder can record up to 14 channels including one voice channel which records on channel 14 and overruns data if recorded on that channel. It has seven variable speeds from 15/16 IPS up to 60 IPS. It can attenuate signals from 0.1 to 20 volts peak to peak normalizing the recorded signal to 1 volt peak to peak output.
ENDECO 956 WAVE TRACK BUOY	This orbital following wave buoy measures wave height and direction. It transmits three digital signals; wave height, buoy tilt (East-West), and buoy tilt (North-South) to a remote receiver usually deployed with the test vessel. The digital signals are recorded and analyzed using an Otrona 8:16 microcomputer. The data can be analyzed using either a "LONGUEST-HIGGONS" or "DIGITAL BAND PASS FILTERING" method. The output is Significant Wave Height (H 1/3) and significant period as well as a plot of wave energy vs. frequency and direction. This allows for a determination of the major swell direction and quantification of the extent of a undirectional or confused sea state. Directional accuracy is ± 10°. It can be moored with an accumulator mooring system for long-term monitoring situations.

HUMAN-RESPONSE VIBRATION METER Type 2512 Bruel & Kjaer (B&K) Marion, MA	Measures vibration from a tri-axial accelerometer for the evaluation of vibration on the human body in agreement with current ISO standards for Hand-Arm and Whole-Body (including motion sickness) measurement. The complex relationship between level, frequency and time is automatically taken into account in the compututation of equivalent continuous vibration level and exposure dose. Outputs are printed on thermal paper with the use of a Alphanumeric Printer type 2312. Outputs are automatically printed at preselected intervals in the form of: Current Time, Elapsed Time, Peak Acceleration (dB), Equivalent Exposure (dB) and Percent of a particular ISO standard selected which has been reached at that elapsed time.
TRIAXIAL SEAT ACCELEROMETER Type 4322 (used with B&K Meter Type 2512)	This accelerometer is especially designed for detecting vibration motion in connection with the measurement of whole-body vibration and can be put under the buttocks of a seated person.
Frequency Range:	0.1 H_z to 2 kHz (+ 5%)
Charge Sensitivity:	1 pC/ms^{-2} $\pm$ 2% 10 pC/g
Piezoelectric Material:	PZ27 Delta Shear Configuration
ACCELEROMETER CHARGE AMPLIFIERS Type 2635 and 2651 Bruel & Kjaer Marion, MA	Various ship vibration measurements are made using Bruel & Kjaer (B&K) accelerometers and charge amplifiers. The output of the charge amplifiers are recorded on magnetic tape. Two types of B&K accelerometers are used; they are the 4368 and the 4384. Two types of charge amplifiers are used; they are the Model 2635 and the Model 2651. The 2365 is a battery operated (stand alone) charge amplifier with transducers sensitivity conditioning from 0.1 to 10.99 pC/ms^{-2}.
Frequency Range:	
Acceleration	.2Hz to 100kHz
Velocity	1Hz to 10kHz
Displacement	1Hz to 1kHz
	The Model 2651 charge amplifier needs a power supply (and is packaged in a pack of four amplifiers with the power supply); transducer sensitivity conditioning settings of 0.1, 1, and 10 mV/pC.

Frequency Range:
Acceleration .003 to 200kHz

General B&K accelerometer information follows:

Model	Charge Sensitivity	Frequency Range	Temperature Range (deg. C)
4368	4.8 pC/ms^{-2}	.2 to 5000	-74 to 250
4384	1 $\pm$ 2%	.2 to 9200	-74 to 250

FUEL FLOW METERS
HEDLAND
Racine, WI

In-line flow meters are direct reading units requiring no electrical connections or readout devices. Scales are based on a specific gravity of 0.84 for fuel oil. Accuracy is within $\pm$ 5% of full scale.

HORSEPOWER METER 1202A (2)
ACUREX AUTODATA,
Mountain View, CA

The 1202A measurement system measures shaft torque and rpm and calculates horsepower from that information (HP = Torque x rpm x Constant). The shaft is strain gauged for torque. A transmitter collar and antenna are bolted to the shaft in order to power and transmit FM signals from the strain gauge bridge. Three simultaneous analog outputs are provided at the readout box (Torque, HP and rpm). Calibration using a shunt resister is usually conducted because a known torque load is difficult to apply to a vessel in the water. This method simulates a torque load by shunting a gauge with a known value of resistance.

SPECIFICATIONS

Accuracy:	Torque	$\pm$ 1% of full scale
	rpm	$\mp$ 0.25% of full scale
	Horsepower	$\mp$ 1.5% of full scale

SOUND LEVEL METER TYPE 213H
Bruel and Kjaer
Marlborough, MA

This hand-held sound level meter measures levels from 50 to 130 dB with A or C weighting filters. It can be used with fast or slow response. Calibration is done by using a Sound Level Calibration unit Type 4230. The sound pressure level of the calibrator is 93.6 dB.

NASA

RIDE QUALITY METER SPECIFICATIONS

Input Power:	12Vdc @ 3.5 A
Size:	6"H x 16"W x 14"D
Weight:	30 lbs
Environment:	10 - 40°C 5 - 95% R.H. (Noncondensing)
Signal Inputs:	<u>Accelerometers (Max Levels)</u> Vertical $\pm$ 2g Lateral $\pm$ 2g Longitudinal $\pm$ 2g Pitch $\pm$ 2 Rad/Sec^2 Roll $\pm$ 2 Rad/Sec^2 <u>Microphone (Range)</u> 50 - 100 dB
Sensitivity:	<u>Accelerometer Inputs</u> $\pm$ 0.1 V to $\pm$ 10.0 V Full Scale <u>Microphone Input</u> $\pm$ 0.05 to $\pm$ 5.0 V Full Scale
Input Independence:	20K OHMS
Filters:	<u>Acceleration</u> Per NASA developed discomfort model (1-30 Hz) <u>Microphone</u> "A" - weighting Six octave bands (63 - 2000 Hz)
Internal Computer:	DEC LSI - 11
Display Type:	3 1/2 Digit LCD

NASA
RIDE QUALITY METER SPECIFICATIONS (continued)

Display Output:	Total Discomfort Individual axis and noise discomfort
Printer Type:	20 - column alphanumeric
Printer Output:	Total discomfort Vibration component of discomfort Noise component of discomfort Individual axis discomfort Individual octave band discomfort Discomfort corrected for trip duration

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APPENDIX B

TABULATED DATA

TABLE B-I

USCGC SEA HAWK
SPEED POWER
WITH TWO LIFT FANS

30 January 1985

DRAFTS 8'0" Fwd; 9'1" Aft
DISPLACEMENT 148.5 LT (Heavy)

SPEED KTS	MAIN ENGINES PORT SRPM	MAIN ENGINES PORT HP	MAIN ENGINES STBD SRPM	MAIN ENGINES STBD HP	TOTAL MAIN ENGINE HORSEPOWER	LIFT ENGINES PORT ERPM	LIFT ENGINES STBD ERPM
7	365	190	310	103	293	1070	1100
11	480	385	470	315	700	1360	1360
17.5	590	679	520	430	1109	1550	1490
19.2	700	1005	700	1000	2005	1576	1625
20.5	720	1035	750	1125	2160	1576	1625
21.5	750	1058	800	1177	2235	1576	1625
22	760	1090	800	1230	2320	1950	1975

TABLE B-II

SES 200
SPEED POWER
WITH FOUR LIFT FANS

28 January 1985

DRAFTS 6'7" Fwd; 8'10" Aft
DISPLACEMENT 189.5 LT (Heavy)
LCG 0.67 Ft Aft Centerline
RCS OFF

SPEED KTS	MAIN ENGINES PORT SRPM	MAIN ENGINES PORT HP	MAIN ENGINES STBD SRPM	MAIN ENGINES STBD HP	TOTAL MAIN ENGINE HORSEPOWER	LIFT ENGINES FWD PORT ERPM	LIFT ENGINES FWD STBD ERPM	LIFT ENGINES AFT PORT ERPM	LIFT ENGINES AFT STBD ERPM
6.3	325	201	337	151	352	1400	1400	700	800
9	498	495	528	545	1040	1600	1600	700	800
13	598	753	595	707	1460	1600	1600	700	800
18	701	980	700	952	1932	1800	1800	700	800
19.7	748	1137	745	1103	2204	1800	1800	700	800
21	804	1336	806	1360	2696	1900	1900	700	800
22.5	828	1452	815	1375	2827	1900	1900	700	800

TABLE B-III

USCGC SEA HAWK
FUEL CONSUMPTION WITH TWO LIFT ENGINES

30 January 1985

DRAFTS 8'0" Fwd; 9'1" Aft
DISPLACEMENT 148.5 LT (Heavy)

SPEED KTS	MAIN ENGINES PORT		MAIN ENGINES STBD		LIFT ENGINES* PORT		LIFT ENGINES* STBD		GENERATOR** GPH	TOTAL FUEL CONSUMPTION GPH
	SRPM	GPH	SRPM	GPH	ERPM	GPH	ERPM	GPH		
7	365	18	310	15	1070	7	1100	7	2	49
11	480	36	470	21	1360	8	1360	8	2	75
17.5	590	54	520	30	1550	8.5	1490	8.5	2	103
19.2	700	66	700	54	1576	9	1625	9	2	140
20.5	720	78	750	66	1576	9	1625	9	2	164
21.5	750	81	800	84	1576	9	1625	9	2	185
22	760	84	800	90	1950	10	1975	10	2	196

* From data collected on CGC SEA HAWK, 9 August 1984

** Estimated fuel consumption for generator

TABLE B-IV

SES-200
FUEL CONSUMPTION WITH FOUR LIFT ENGINES

28 January 1985

DRAFTS 6'7" Fwd; 8'10" Aft
DISPLACEMENT 189.5 LT (Heavy)
LCG 0.67 Ft Aft Centerline
RCS OFF

SPEED KTS	MAIN ENGINES				LIFT ENGINES								GENERATOR*** CONSUMPTION GPH	TOTAL FUEL CONSUMPTION
					FORWARD*				AFT**					
	PORT		STBD		PORT		STBD		PORT		STBD			
	SRPM	GPH	SRPM	GPH	ERPM	GPH	ERPM	GPH	ERPM	GPH	ERPM	GPH		
6.3	325	12	330	10	1400	8	1400	8	700	7.5	800	7.5	2	55
9	499	21	540	17	1600	9	1600	9	700	7.5	800	7.5	2	73
13	600	30	595	36	1600	9	1600	9	700	7.5	800	7.5	2	101
18	700	39	700	39	1800	9.5	1800	9.5	700	7.5	800	7.5	2	114
19.7	748	57	745	46.5	1800	9.5	1800	9.5	700	7.5	800	7.5	2	139.5
21	804	66	805	63	1800	9.5	1800	9.5	700	7.5	800	7.5	2	165
22.5	827	72	815	69	1900	10	1900	10	700	7.5	800	7.5	2	178

* From data collected during previous tests. Fwd lift engine fuel flow meters were not operating properly.

** Aft lift engines were run at idle speed because they were out of balance and would vibrate excessively at normal operating RPM (i.e., 1400-1800 ERPM).

*** Estimated fuel consumption for generator.

TABLE B-V

USCGC SEA HAWK
RANGE AND FUEL EFFICIENCY DATA
TWO MAIN ENGINES AND TWO LIFT ENGINES

30 January 1985

DRAFTS 8'0" Fwd; 9'1" Aft
DISPLACEMENT 148.5 LT (Heavy)
LCG 1.4 Ft Fwd Centerline

Fuel 7342 Gal.
% Usable 95%
Usable 6975 Gal.

SPEED (KNOTS)	TOTAL FUEL CONSUMPTION (GPH)	RANGE (NM)	ENDURANCE (DAYS)	FUEL EFFICIENCY (GAL/NM)
7.0	49.0	996	5.9	7.00
11.0	75.0	1023	3.9	6.82
17.5	103.0	1185	2.8	5.89
19.2	140.0	957	2.1	7.29
20.5	164.0	872	1.8	8.00
21.5	185.0	811	1.6	8.60
22.0	196.0	783	1.5	8.91

TABLE B-VI

SES-200
RANGE AND FUEL EFFICIENCY DATA
TWO MAIN ENGINES AND FOUR LIFT ENGINES

29 January 1985

DRAFTS 6'7" Fwd; 8'10" Aft
DISPLACEMENT 189.5 LT (Heavy)
LCG 0.67 Ft Aft Centerline
RCS OFF

Fuel 18390 Gal.
% Usable 95%
Usable 17470 Gal.

SPEED (KNOTS)	TOTAL FUEL CONSUMPTION (GPH)	RANGE (NM)	ENDURANCE (DAYS)	FUEL EFFICIENCY (GAL/NM)
6.3	55.0	2001	13.2	8.73
9.0	73.0	2154	10.0	8.11
13.0	101.0	2249	7.2	7.77
18.0	114.0	2759	6.4	6.33
19.7	139.5	2467	5.2	7.08
21.0	165.0	2224	4.4	7.86
22.5	178.0	2208	4.1	7.91

TABLE B-VII

NOISE LEVELS
USCGC SEA HAWK (WSES-2)
2 February 1985

COMPARTMENT OR LOCATION	Speed 7 Kts — TWO ENGINES, TWO LIFT FANS, Mains 800 ERPM, Lifts 1300 ERPM — WEIGHTING (dB)*		Speed 20 Kts — TWO ENGINES, TWO LIFT FANS, Mains 1475 ERPM, Lifts 1900 ERPM — WEIGHTING (dB)*	
	A	C	A	C
Main Deck Passageway	69.3	86.5	80.0	97.0
Mess Deck	72.0	84.5	82.5	96.0
Aft Berthing	76.0	91.5	86.5	99.0
Bridge**	71.0	89.5	83.0	97.0
Engine Room	105.0	109.0	115.0	118.0
Generator Room	102.0	104.5	98.5	106.5
Phone Booth (Gen. Room)	86.5	99.0	92.0	108.5

* Meter used in slow response mode.

** Calm water operation, wind light and variable, bridge outside doors open.

TABLE B-VIII

NOISE LEVELS
SES-200
28 January 1985

TWO MAIN ENGINES AND FOUR LIFT ENGINES

	Speed 6.3 Kts		Speed 13 Kts		Speed 19.7 Kts		Speed 22.5 Kts	
	Mains 650 ERPM Fwd Lifts 1400 ERPM Aft Lifts 750 ERPM		Mains 1200 ERPM Fwd Lifts 1400 ERPM Aft Lifts 750 ERPM		Mains 1500 ERPM Fwd Lifts 1900 ERPM Aft Lifts 750 ERPM		Mains 1680 ERPM Fwd Lifts 1900 ERPM Aft Lifts 750 ERPM	
	WEIGHTING (dB)*		WEIGHTING (dB)*		WEIGHTING (dB)*		WEIGHTING (dB)*	
	A	C	A	C	A	C	A	C
Main Deck Passageway**	76	91	79	97	82	96	83	97
Mess Deck	78	87	80	89	85	92	86	95
Bridge**	72	89	76	93	78	94	77	93
Engine Room	100	105	102	111	94	100	104	109
Outside Main Deck (Next to Fwd. Fan Intake)	--	--	--	--	97	108	96	107

* Meter used in slow response mode.

** Normal operations with outside doors open.

-- Data not collected.

TABLE B-IX

USCGC SEA HAWK (WSES-2)
TACTICAL DATA

Degrees Rudder	DISTANCE IN METERS: Advance at 90° Course Change	Maximum Path Advance	Transfer at 90° Course Change	Maximum Path Transfer	Tactical Diameter	TIME IN SECONDS: Time to 90° Course Change	Time to 360° Course Change
	SPEED 8 KTS MAINS 1000 RPM		TWO LIFT ENGINES 1200 RPM				
10 Right	320	330	140	185	300	92	360
10 Left	300	370	160	180	550	--	--
20R	220	280	40	110	190	72	232
20L	215	230	110	180	340	51	268
30R	165	200	40	90	140	55	196
30L	170	270	50	140	250	49	196

Note: A 12-knot wind off port beam at start of turn caused a significant increase of tactical diameters when turning to the left.

Degrees Rudder	Advance at 90° Course Change	Maximum Path Advance	Transfer at 90° Course Change	Maximum Path Transfer	Tactical Diameter	Time to 90° Course Change	Time to 360° Course Change
	SPEED 16 KTS MAINS 1350 RPM		TWO LIFT ENGINES 1400 RPM				
10 Right	470	610	110	290	620	72	251
10 Left	430	510	80	180	360	72	224
20R	220	250	35	170	290	44	171
20L	330	380	20	120	230	41	153
30R	230	300	0	110	210	32	128
30L	220	350	30	120	210	40	144
	SPEED 17 KTS MAINS 1400 RPM		ONE LIFT ENGINE 1400 RPM				
10 Right	380	440	110	380	700	63	244
10 Left	460	550	135	330	580	64	224
20R	205	320	35	180	330	39	144
20L	380	440	65	130	340	28	136
30R	260	330	25	90	260	32	124
30L	310	350	35	90	200	32	126
	SPEED 20 KTS MAINS 1450 RPM		TWO LIFT ENGINES 1500 RPM				
10 Right	495	560	105	220	440	55	--
10 Left	460	570	30	120	305	36	--
20R	330	400	85	100	260	40	140
20L	270	650	0	120	260	36	120
30R	250	320	40	80	180	31	112
30L	310	340	40	75	200	32	--

TABLE B-X

USN SES-200
TACTICAL DATA - (From Reference 3)

Degrees Rudder	Tactical Diameter (meters)	Time to 180° Course Change (seconds)
	SPEED 10 KTS	
10 Right	1158	270
10 Left	896	222
20 Right	460	120
20 Left	460	120
30 Right	320	90
30 Left	320	90
	SPEED 20 KTS	
10 Right	1400	264
10 Left	1160	210
20 Right	762	126
20 Left	670	120
30 Right	426	72
30 Left	305	72
	SPEED 29 KTS	
10 Right	1676	183
10 Left	1700	190
20 Right	868	120
20 Left	675	108
30 Right	395	69
30 Left	460	81

TABLE B-XI
USCGC SEA HAWK SEAKEEPING
3.5 - 4.4 FT SIGNIFICANT SEAS
SPEED 18 KNOTS
27 JANUARY 1985

RELATIVE SEA DIRECTION/(H 1/3)*	AVERAGING TYP	ROLL ANGLE DEG	PITCH ANGLE DEG	ACCELERATIONS IN G'S: VERTICAL CG	VERTICAL BERTHING	VERTICAL MESS DECK	VERTICAL BRIDGE	SURGE CG	SWAY CG	ROLL RATE DEG/SEC	PITCH RATE DEG/SEC
HEAD (4.4 FT)	H 1/10	N/A	N/A	.319	N/A	.412	.490	.080	.052	2.026	3.645
	H 1/3	"	"	.239	"	.311	.348	.064	.041	1.534	2.892
	RMS	"	"	.172	"	.217	.244	.046	.030	1.105	2.059
	MEAN	"	"	.154	"	.191	.206	.042	.027	.96	1.847
	HIGHEST	"	"	.645	"	.769	1.182	.117	.084	2.913	5.270
BOW QUARTER (3.5 FT)	H 1/10	N/A	N/A	.355	N/A	.390	.557	.070	.106	4.600	2.763
	H 1/3	"	"	.265	"	.296	.401	.055	.085	3.674	2.147
	RMS	"	"	.186	"	.206	.271	.041	.061	2.60	1.532
	MEAN	"	"	.164	"	.181	.225	.037	.055	2.31	1.374
	HIGHEST	"	"	.626	"	.619	.876	.096	.147	7.134	3.803
BEAM (3.7 FT)	H 1/10	N/A	N/A	.150	N/A	.186	.475	.047	.066	4.72	1.70
	H 1/3	"	"	.127	"	.154	.350	.037	.052	3.68	1.36
	RMS	"	"	.097	"	.115	.232	.026	.036	2.63	.98
	MEAN	"	"	.092	"	.108	.195	.023	.032	2.34	.89
	HIGHEST	"	"	.182	"	.261	.600	.065	.085	6.97	2.24
STERN QUARTER (3.5 FT)	H 1/10	N/A	N/A	.264	N/A	.299	.419	.054	.082	3.262	2.253
	H 1/3	"	"	.185	"	.223	.298	.044	.064	2.504	1.813
	RMS	"	"	.135	"	.161	.207	.032	.046	1.787	1.309
	MEAN	"	"	.120	"	.145	.177	.029	.041	1.589	1.192
	HIGHEST	"	"	.631	"	.600	.704	.072	.110	4.447	2.859
FOLLOWING (3.5 FT)	H 1/10	N/A	N/A	.228	N/A	.277	.436	.067	.075	2.713	2.938
	H 1/3	"	"	.166	"	.208	.313	.053	.059	2.173	2.236
	RMS	"	"	.121	"	.151	.213	.038	.041	1.550	1.564
	MEAN	"	"	.110	"	.136	.180	.034	.037	1.388	1.371
	HIGHEST	"	"	.395	"	.637	.636	.096	.135	4.502	4.481

* (H 1/3) = Significant Wave Height

TABLE B-XII
SES-200 SEAKEEPING
3.5 - 4.4 FT SIGNIFICANT SEAS
SPEED 18 KNOTS
27 JANUARY 1985

SINGLE AMPLITUDE SHIP MOTIONS

RELATIVE SEA DIRECTION/(H 1/3)*	AVERAGING TYPE RCS	ROLL ANGLE DEG OFF ON	PITCH ANGLE DEG OFF ON	ACCELERATIONS IN G'S: VERTICAL CG OFF ON	VERTICAL BERTHING OFF ON	VERTICAL MESS DECK OFF ON	VERTICAL BRIDGE OFF ON	SURGE CG OFF ON	SWAY CG OFF ON	ROLL RATE DEG/SEC OFF ON	PITCH RATE DEG/SEC OFF ON
HEAD (4.4 FT)	H 1/10	1.877/2.028	6.015/3.466	.236/.125	N/A	N/A	N/A	.083/.098	.108/.118	1.867/1.936	1.413/1.370
	H 1/3	1.459/1.552	3.876/2.105	.153/.098	"	"	"	.065/.074	.084/.095	1.418/1.473	1.105/1.011
	RMS	1.005/1.059	2.625/1.531	.103/.067	"	"	"	.044/.051	.059/.068	.971/1.024	.785/ .722
	MEAN	.879/ .913	1.964/1.113	.079/.025	"	"	"	.038/.043	.051/.061	.838/ .893	.704/ .639
	HIGHEST	2.598/3.328	12.009/8.723	.450/.295	"	"	"	.123/.153	.167/.190	2.824/3.303	2.273/3.888
BOW QUARTER (3.5 FT)	H 1/10	4.408/3.702	1.467/1.926	.077/.077	"	"	"	.221/.209	.082/.095	1.446/1.596	1.088/ .947
	H 1/3	3.424/2.946	1.196/1.538	.061/.057	"	"	"	.165/.160	.062/.073	1.111/1.249	.839/ .751
	RMS	2.341/2.068	.875/1.063	.042/.038	"	"	"	.106/.105	.043/.051	.770/ .863	.603/ .543
	MEAN	1.984/1.822	.805/ .937	.037/.032	"	"	"	.083/.084	.038/.045	.677/ .759	.545/ .497
	HIGHEST	5.605/5.066	1.710/2.511	.096/.114	"	"	"	.301/.299	.125/.140	1.868/2.220	2.069/1.446
BEAM (3.7 FT)	H 1/10	3.752/ -	1.225/ -	.063/ -	"	"	"	.190/ -	.080/ -	1.383/ -	1.096/ -
	H 1/3	2.985/ -	1.030/ -	.050/ -	"	"	"	.145/ -	.063/ -	1.079/ -	.797/ -
	RMS	2.121/ -	.761/ -	.034/ -	"	"	"	.095/ -	.044/ -	.757/ -	.571/ -
	MEAN	1.867/ -	.708/ -	.030/ -	"	"	"	.076/ -	.039/ -	.673/ -	.507/ -
	HIGHEST	5.081/ -	1.542/ -	.081/ -	"	"	"	.282/ -	.123/ -	2.484/ -	2.088/ -
STERN QUARTER (3.5 FT)	H 1/10	2.737/2.592	1.887/1.756	.096/.091	"	"	"	.130/.138	.105/.079	1.815/1.455	.897/ .968
	H 1/3	2.110/2.090	1.569/1.421	.077/.072	"	"	"	.097/.104	.078/.058	1.345/1.095	.690/ .703
	RMS	1.465/1.432	1.112/1.011	.053/.048	"	"	"	.066/.070	.054/.040	.928/ .762	.505/ .505
	MEAN	1.269/1.243	1.004/ .913	.045/.040	"	"	"	.055/.059	.046/.034	.799/ .668	.461/ .450
	HIGHEST	3.783/3.560	2.315/2.328	.124/.119	"	"	"	.203/.181	.163/.114	2.659/2.089	1.759/1.789
FOLLOWING (ABORTED)											

* (H 1/3) = Significant Wave Height
\- Data Not Collected

TABLE B-XIII
USCGC SEA HAWK AND SES-200 SEAKEEPING
2.2 FT SIGNIFICANT SEAS
SPEED 18 KNOTS
28 JANUARY 1985

USCGC SEA HAWK SINGLE AMPLITUDE SHIP MOTIONS

RELATIVE SEA DIRECTION/(H 1/3)*	AVERAGING TYPE	ROLL ANGLE DEG	PITCH ANGLE DEG	ACCELERATIONS IN G'S VERTICAL CG	VERTICAL BERTHING	VERTICAL MESS DECK	VERTICAL BRIDGE	SURGE CG	SWAY CG	ROLL RATE DEG/SEC	PITCH RATE DEG/SEC
USCGC SEA HAWK	H 1/10	1.46	.77	.151	.236	.276	.82	.083	.060	2.08	1.27
	H 1/3	.99	.58	.118	.158	.191	.56	.031	.044	1.64	1.00
HEAD	RMS	.78	.44	.084	.116	.133	.39	.023	.034	1.17	.72
(2.2 FT)	MEAN	.60	.41	.074	.102	.114	.28	.021	.029	1.05	.65
	HIGHEST	6.47	1.28	.247	.545	.416	1.97	.093	.157	2.61	1.93

USN SES-200 SINGLE AMPLITUDE SHIP MOTIONS

RELATIVE SEA DIRECTION/(H 1/3*)	AVERAGING TYPE	ROLL ANGLE DEG	PITCH ANGLE DEG	ACCELERATIONS IN G'S VERTICAL CG	VERTICAL BERTHING	VERTICAL MESS DECK	VERTICAL BRIDGE	SURGE CG	SWAY CG	ROLL RATE DEG/SEC	PITCH RATE DEG/SEC
	RCS	OFF ON	OFF ON	OFF ON	OFF ON	OFF ON	OFF ON	OFF ON	OFF ON	OFF ON	OFF ON
SES-200	H 1/10	1.60/1.49	.82/.90	.036/.043	.070/.076	.163/.164	.520/.525	.086/.105	.049/.079	.89/1.27	6.9/5.1
	H 1/3	1.28/1.18	.66/.74	.028/.032	.063/.068	.143/.144	.462/.461	.065/.083	.039/.055	.73/1.04	5.0/3.4
HEAD	RMS	.93/ .86	.50/.55	.020/.023	.052/.061	.117/.117	.384/.380	.044/.058	.028/.048	.53/ .75	3.1/2.3
(2.2 FT)	MEAN	.86/ .79	.47/.51	.019/.021	.050/.051	.114/.114	.375/.370	.038/.051	.026/.044	.50/ .70	2.9/1.9
	HIGHEST	2.02/2.10	1.07/1.15	.062/.064	.104/.096	.248/.242	.725/.750	.131/.154	.081/.118	1.45/1.82	13.5/11.3

* (H 1/3) = Significant Wave Height

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TABLE B-XIV
USCGC SEA HAWK SEAKEEPING
4.0 FT SIGNIFICANT SEAS
SPEED 20 KNOTS
31 JANUARY 1985

SINGLE AMPLITUDE SHIP MOTIONS

RELATIVE SEA DIRECTION/(H 1/3)*	AVERAGING TYPE	ROLL ANGLE DEG	PITCH ANGLE DEG	ACCELERATIONS IN G'S VERTICAL CG	VERTICAL BERTHING	VERTICAL MESS DECK	VERTICAL BRIDGE	SURGE CG	SWAY CG	ROLL RATE DEG/SEC	PITCH RATE DEG/SEC
HEAD (4.0 FT)	H 1/10	2.301	3.350	.383	.394	.560	.719	.038	.100	5.422	5.531
	H 1/3	1.719	2.747	.283	.302	.430	.509	.031	.077	3.945	4.531
	RMS	1.170	1.991	.201	.215	.300	.351	.023	.053	2.798	3.224
	MEAN	.985	1.812	.178	.192	.262	.292	.022	.046	2.444	2.908
	HIGHEST	4.241	4.466	.741	.691	.839	1.431	.069	.149	9.340	7.651
BOW QUARTER (4.0 FT)	H 1/10	3.635	3.313	.388	.390	.546	.644	.040	.068	5.166	5.910
	H 1/3	2.873	2.642	.287	.296	.419	.459	.032	.056	4.100	4.682
	RMS	1.898	1.888	.202	.208	.292	.318	.024	.040	2.966	3.372
	MEAN	1.554	1.702	.176	.184	.255	.267	.023	.037	2.669	3.042
	HIGHEST	5.228	4.731	.757	.678	.774	1.121	.065	.101	6.823	9.390
BEAM (4.0 FT)	H 1/10	5.810	2.378	.281	.256	.321	.664	.031	.074	6.992	2.272
	H 1/3	4.194	1.822	.199	.188	.238	.469	.026	.059	5.413	1.776
	RMS	2.790	1.268	.143	.137	.172	.318	.020	.042	3.809	1.264
	MEAN	2.188	1.101	.126	.123	.153	.256	.019	.037	3.327	1.125
	HIGHEST	10.811	4.964	.569	.546	.701	1.503	.036	.108	13.363	3.791
STERN QUARTER (4.0 FT)	H 1/10	2.880	3.725	.199	.083	.195	.548	.039	.064	4.663	1.697
	H 1/3	2.167	2.660	.148	.077	.153	.377	.031	.049	3.703	1.329
	RMS	1.436	1.881	.110	.067	.114	.260	.023	.035	2.592	.935
	MEAN	1.182	1.543	.100	.066	.106	.216	.022	.031	2.285	.828
	HIGHEST	3.860	9.242	.400	.087	.318	.861	.061	.113	7.076	3.174
FOLLOWING (4.0 FT)	H 1/10	2.804	2.883	.187	.081	.174	.511	.037	.058	4.203	1.697
	H 1/3	2.115	2.230	.140	.075	.138	.341	.028	.046	3.231	1.303
	RMS	1.400	1.521	.104	.066	.105	.233	.021	.032	2.239	.913
	MEAN	1.146	1.302	.096	.065	.099	.187	.020	.029	1.933	.803
	HIGHEST	3.770	4.486	.370	.10[illegible]	.307	.823	.050	.086	7.641	3.196

* (H 1/3) = Significant Wave Height

TABLE B-XV
SES-200 SEAKEEPING
4.0 FT SIGNIFICANT SEAS
SPEED 20 KNOTS
31 JANUARY 1985

SINGLE AMPLITUDE SHIP MOTIONS

RELATIVE SEA DIRECTION/(H 1/3)*	AVERAGING TYPE	ROLL ANGLE DEG	PITCH ANGLE DEG	ACCELERATIONS IN G'S VERTICAL CG	VERTICAL BERTHING	VERTICAL MESS DECK	VERTICAL BRIDGE	SURGE CG	SWAY CG	ROLL RATE DEG/SEC	PITCH RATE DEG/SEC
	RCS	OFF ON	OFF ON	OFF ON	OFF ON	OFF ON	OFF ON	OFF ON	OFF ON	OFF ON	OFF ON
HEAD (4.0 FT)	H 1/10	3.3/2.4	2.7/2.7	.139/.129	N/A	N/A	.491/.491	.211/.151	.136/.128	2.56/2.43	1.22 /.947
	H 1/3	2.6/1.9	2.2/2.3	.116/.114	"	"	.435/.434	.165/.121	.111/.105	2.08/1.93	.900/.708
	RMS	1.9/1.4	1.6/1.9	.092/.091	"	"	.362/.362	.117/.085	.081/.072	1.41/1.26	.613/.479
	MEAN	1.7/1.3	1.4/1.8	.089/.088	"	"	.354/.354	.104/.073	.074/.062	1.16/1.02	.511/.399
	HIGHEST	4.9/4.0	3.5/3.5	.172/.187	"	"	.721/.972	.335/.218	.191/.185	3.76/3.73	2.39 /1.57
BOW QUARTER (4.0 FT)	H 1/10	3.0/3.1	2.4/2.3	.127/.120	"	"	.490/.494	.186/.193	.145/.138	2.44/2.50	1.037/.914
	H 1/3	2.4/2.5	1.9/1.9	.103/.102	"	"	.434/.436	.149/.157	.119/.118	1.85/2.02	.759/.675
	RMS	1.7/1.8	1.4/1.4	.077/.077	"	"	.364/.364	.108/.119	.093/.094	1.19/1.33	.521/.459
	MEAN	1.5/1.6	1.3/1.3	.072/.073	"	"	.356/.356	.099/.113	.089/.091	.922/1.06	.435/.383
	HIGHEST	4.5/4.7	3.5/3.4	.189/.168	"	"	.695/.708	.250/.265	.192/.179	4.10/3.51	2.562/2.219
BEAM (4.0 FT)	H 1/10	5.9/5.1	1.6/2.3	.127/.103	"	"	.474/.500	.040/.020	.195/.065	2.05/1.16	1.18 / .776
	H 1/3	4.5/4.1	1.1/1.8	.099/.073	"	"	.425/.440	.031/.017	.173/.052	1.64/ .836	.857/ .617
	RMS	3.1/2.9	1.1/1.3	.068/.047	"	"	.358/.367	.023/.014	.132/.036	1.12/ .561	.568/ .476
	MEAN	2.6/2.5	1.0/1.1	.059/.037	"	"	.351/.359	.020/.014	.125/.031	.95/ .458	.452/ .448
	HIGHEST	8.8/6.5	2.1/3.5	.208/.177	"	"	.558/.666	.100/.022	.248/.089	2.72/1.81	1.93 /1.71
STERN QUARTER (4.0 FT)	H 1/10	3.9/3.8	2.9/2.6	.127/.106	"	"	.491/.496	.014/.014	051/.048	.851/ .843	.502/.455
	H 1/3	3.0/3.0	2.4/2.0	.028/.060	"	"	.437/.439	.010/.011	.040/.038	.644/ .636	.378/.346
	RMS	2.1/2.1	1.7/1.4	.053/.042	"	"	.365/.366	.007/.007	.028/.027	.445/ .440	.264/.241
	MEAN	1.8/1.8	1.5/1.2	.037/.030	"	"	.358/.359	.006/.006	.025/.024	.382/ .378	.230/.210
	HIGHEST	5.7/7.0	3.6/3.1	.176/.163	"	"	.709/.807	.021/.023	.075/.065	1.51 /1.34	.858/.892
FOLLOWING (4.0 FT)	H 1/10	3.8/3.3	2.6/2.5	.091/.138	"	"	.495/.492	.019/.019	.051/.054	.859/ .801	.465/.596
	H 1/3	2.9/2.5	1.8/2.0	.050/.117	"	"	.440/.439	.016/.017	.039/.046	.649/ .619	.353/.469
	RMS/3	2.0/1.8	1.2/1.4	.036/.083	"	"	.367/.371	.014/.014	.028/.038	.449/ .431	.248/.374
	MEAN	1.7/1.5	1.0/1.3	.026/.075	"	"	.360/.364	.013/.013	.025/.037	.387/ .373	.218/.363
	HIGHEST	5.7/5.3	3.7/4.0	.194/.205	"	"	.695/.645	.023/.021	.073/.070	1.36 /1.605	.892/.663

* (H 1/3) = Significant Wave Height

TABLE B-XVI
USCGC SEA HAWK AND SES-200 SEAKEEPING
6.4 FT SIGNIFICANT SEAS
SPEED 20 KNOTS
31 JANUARY 1985

USCGC SEA HAWK SINGLE AMPLITUDE SHIP MOTIONS

RELATIVE SEA DIRECTION/(H 1/3)*	AVERAGING TYPE	ROLL ANGLE DEG	PITCH ANGLE DEG	ACCELERATIONS IN G'S VERTICAL CG	VERTICAL BERTHING	VERTICAL MESS DECK	VERTICAL BRIDGE	SURGE CG	SWAY CG	ROLL RATE DEG/SEC	PITCH RATE DEG/SEC
USCGC SEA HAWK	H 1/10	3.425	5.813	.538	.535	.876	.911	.059	.083	5.137	10.098
	H 1/3	2.500	4.417	.388	.404	.633	.598	.045	.067	4.091	7.520
HEAD	RMS	1.713	3.147	.268	.280	.436	.403	.033	.048	2.902	5.393
(6.4 FT)	MEAN	1.440	2.796	.229	.242	.366	.315	.030	.043	2.574	4.797
	HIGHEST	4.688	8.484	.935	.919	1.543	1.613	.085	.127	10.335	15.565

USN SES-200 SINGLE AMPLITUDE SHIP MOTIONS

RELATIVE SEA DIRECTION/(H 1/3)*	AVERAGING TYPE RCS	ROLL ANGLE DEG OFF ON	PITCH ANGLE DEG OFF ON	ACCELERATIONS IN G'S VERTICAL CG OFF ON	VERTICAL BERTHING OFF ON	VERTICAL MESS DECK OFF ON	VERTICAL BRIDGE OFF ON	SURGE CG OFF ON	SWAY CG OFF ON	ROLL RATE DEG/SEC OFF ON	PITCH RATE DEG/SEC OFF ON
SES-200	H 1/10	1.827/2.647	.509/.650	.154/.149	N/A	N/A	.502/.490	.096/.090	.146/.171	2.818/3.219	1.597/1.775
	H 1/3	1.444/2.036	.454/.543	.121/.124	"	"	.438/.434	.076/.071	.123/.132	2.388/2.498	1.057/1.256
HEAD	RMS	1.072/1.456	.342/.419	.088/.096	"	"	.364/.360	.055/.051	.084/.090	1.528/1.718	.731/ .894
(6.4 FT)	MEAN	.989/1.319	.323/.402	.078/.092	"	"	.356/.352	.051/.046	.073/.076	1.405/1.464	.577/ .758
	HIGHEST	2.339/3.403	.570/.778	.218/.185	"	"	.652/.645	.109/.114	.158/.230	3.165/4.456	2.987/4.998
SES-200	H 1/10	2.420/4.154	.734/.672	.160/.169	"	"	.509/.498	.087/.133	.193/.197	3.593/3.726	1.575/1.588
BOW	H 1/3	1.935/3.166	.610/.534	.119/.138	"	"	.446/.438	.070/.099	.141/.152	2.677/2.843	1.154/1.184
QUARTER	RMS	1.365/2.203	.454/.369	.083/.101	"	"	.370/.368	.051/.070	.098/.105	1.866/1.910	.814/ .836
(6.4 FT)	MEAN	1.220/1.927	.432/.326	.072/.094	"	"	.361/.360	.046/.062	.082/.090	1.586/1.584	.708/ .730
	HIGHEST	2.887/5.203	.796/.775	.208/.196	"	"	.817/.653	.138/.192	.304/.267	5.661/5.166	3.159/3.668
SES-200	H 1/10	3.214/5.605	.539/.378	.124/.088	"	"	.489/.483	.106/.120	.147/.089	2.821/1.750	1.532/1.312
	H 1/3	2.413/4.280	.423/.306	.099/.062	"	"	.439/.433	.082/.099	.118/.073	2.219/1.369	1.187/ .995
BEAM	RMS	1.700/2.968	.310/.219	.069/.040	"	"	.367/.364	.058/.071	.082/.051	1.531/ .919	.831/ .707
(6.4 FT)	MEAN	1.516/2.584	.286/.199	.060/.031	"	"	.359/.357	.053/.065	.072/.045	1.305/ .782	.734/ .633
	HIGHEST	3.843/6.954	.680/.437	.164/.121	"	"	.606/.624	.141/.140	.180/.104	3.579/2.090	3.110/1.840
SES-200	H 1/10	4.972/3.659	.294/.297	.069/.062	"	"	.495/.496	.116/.082	.076/.043	1.427/ .857	1.354/1.333
STERN	H 1/3	3.934/2.855	.218/.208	.046/.036	"	"	.437/.435	.093/.062	.061/.035	1.161/ .672	1.039/ .973
QUARTER	RMS	2.684/2.001	.143/.133	.030/.026	"	"	.364/.366	.065/.045	.043/.025	.784/ .480	.739/ .681
(6.4 FT)	MEAN	2.324/1.732	.114/.096	.023/.020	"	"	.356/.358	.059/.041	.038/.023	.678/ .438	.660/ .594
	HIGHEST	6.511/5.768	.387/.399	.112/.109	"	"	.650/.637	.143/.128	.104/.056	2.037/1.190	2.283/2.313

* (H 1/3) = Significant Wave Height

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TABLE B-XVII
USCGC SEA HAWK SEAKEEPING
3.4 - 3.9 FT SIGNIFICANT SEAS
SPEED 20 KNOTS
2 FEBRUARY 1985

SINGLE AMPLITUDE SHIP MOTIONS

RELATIVE SEA DIRECTION/(H 1/3)*	AVERAGING TYPE	ROLL ANGLE DEG	PITCH ANGLE DEG	ACCELERATIONS IN G'S						ROLL RATE DEG/SEC	PITCH RATE DEG/SEC
				VERTICAL CG	VERTICAL BERTHING	VERTICAL MESS DECK	VERTICAL BRIDGE	SURGE CG	SWAY CG		
HEAD (3.4 FT)	H 1/10	3.821	1.858	.293	.276	.364	.655	.051	.059	5.580	2.812
	H 1/3	2.985	1.492	.225	.215	.286	.476	.041	.047	4.415	2.233
	RMS	1.980	1.078	.162	.155	.200	.330	.030	.035	3.105	1.600
	MEAN	1.630	.980	.146	.141	.178	.272	.028	.032	2.746	1.440
	HIGHEST	5.806	2.724	.542	.394	.545	2.18	.073	.103	7.647	4.150
BOW QUARTER (3.9 FT)	H 1/10	3.760	2.248	.284	.282	.374	.674	.055	.055	4.856	3.161
	H 1/3	2.594	1.758	.209	.208	.280	.477	.043	.044	3.826	2.466
	RMS	1.753	1.256	.151	.151	.197	.325	.031	.032	2.672	1.772
	MEAN	1.337	1.126	.135	.136	.173	.268	.029	.029	2.345	1.595
	HIGHEST	7.594	3.408	.519	.490	.729	1.168	.083	.078	7.473	4.509
BEAM (3.9 FT)	H 1/10	3.451	2.276	.279	.289	.409	.698	.050	.066	5.211	2.162
	H 1/3	2.529	1.714	.205	.214	.306	.495	.039	.050	3.932	1.720
	RMS	1.723	1.181	.147	.156	.218	.341	.028	.036	2.799	1.239
	MEAN	1.387	1.021	.131	.142	.193	.281	.026	.032	2.474	1.120
	HIGHEST	8.722	3.472	.472	.459	.692	1.359	.078	.098	8.283	3.112
STERN QUARTER (3.4 FT)	H 1/10	3.513	2.608	.320	.298	.391	.617	.057	.064	5.783	4.077
	H 1/3	2.778	2.080	.230	.221	.299	.462	.046	.052	4.579	3.295
	RMS	1.869	1.497	.163	.156	.212	.312	.033	.037	3.298	2.368
	MEAN	1.562	1.353	.143	.139	.189	.262	.031	.034	2.960	2.136
	HIGHEST	5.635	3.818	.598	.407	.571	.837	.078	.086	7.661	5.436
FOLLOWING (3.4 FT)	H 1/10	4.585	2.171	.258	.234	.245	.438	.047	.061	5.216	2.219
	H 1/3	3.404	1.710	.177	.167	.184	.314	.038	.046	4.009	1.650
	RMS	2.189	1.189	.128	.122	.133	.216	.027	.032	2.801	1.164
	MEAN	1.694	1.046	.113	.110	.120	.182	.025	.028	2.444	1.025
	HIGHEST	7.597	2.696	.489	.408	.489	.757	.062	.086	7.519	3.316

* (H 1/3) = Significant Wave Height

TABLE B-XVIII
SES-200 SEAKEEPING
3.4 - 3.9 FT SIGNIFICANT SEAS
SPEED 20 KNOTS
2 FEBRUARY 1985

SINGLE AMPLITUDE SHIP MOTIONS

RELATIVE SEA DIRECTION/(H 1/3)*	AVERAGING TYPE RCS	ROLL ANGLE DEG OFF ON	PITCH ANGLE DEG OFF ON	ACCELERATIONS IN G'S: VERTICAL CG OFF ON	VERTICAL BERTHING OFF ON	VERTICAL MESS DECK OFF ON	VERTICAL BRIDGE OFF ON	SURGE CG OFF ON	SWAY CG OFF ON	ROLL RATE DEG/SEC OFF ON	PITCH RATE DEG/SEC OFF ON
HEAD (3.4 FT)	H 1/10	4.36/4.57	1.83/1.99	.108/.085	N/A	N/A	.525/.451	.037/.040	.025/ -	4.45/5.08	1.84/2.06
	H 1/3	3.40/3.69	1.51/1.54	.090/.072	"	"	.391/.326	.030/.032	.021/.016	3.62/4.19	1.45/1.64
	RMS	2.40/2.59	1.07/1.12	.072/.061	"	"	.267/.221	.022/.024	.017/.012	2.63/2.99	1.01/1.13
	MEAN	2.13/2.30	.96/1.02	.070/.060	"	"	.228/.184	.021/.022	.017/.012	2.37/2.68	.89/ .98
	HIGHEST	5.38/5.47	2.27/2.57	.120/.098	"	"	.778/.855	.052/.061	.027/.019	5.97/7.22	2.47/2.68
BOW QUARTER (3.9 FT)	H 1/10	4.48/4.00	2.11/2.34	.099/.075	"	"	.415/.329	.040/.039	- / -	2.41/2.06	1.83/1.92
	H 1/3	3.54/3.14	1.66/1.83	.084/.071	"	"	.309/.254	.032/.031	.012/.012	1.88/1.69	1.49/1.45
	RMS	2.49/2.20	1.15/1.25	.068/.061	"	"	.216/.177	.023/.023	.011/.011	1.35/1.25	1.04/ .96
	MEAN	2.20/1.94	1.01/1.10	.067/.061	"	"	.188/.157	.022/.021	.011/.011	1.22/1.15	.91/ .80
	HIGHEST	5.21/5.18	2.90/2.89	.123/.075	"	"	.632/.469	.065/.060	.012/.012	2.83/2.70	2.45/2.78
BEAM (3.9 FT)	H 1/10	4.03/3.74	2.06/2.10	.075/.039	"	"	.347/	.034/.033	- /.024	2.46/2.32	2.47/1.29
	H 1/3	3.24/2.98	1.69/1.5	.071/.031	"	"	.265/	.028/.027	.012/.021	1.96/1.84	1.97/ .99
	RMS	2.27/2.10	1.21/1.08	.061/.024	"	"	.185/	.021/.020	.011/.017	1.38/1.32	1.31/ .68
	MEAN	1.18/1.88	1.11/0.92	.060/.023	"	"	.162/	.020/.019	.011/.016	1.22/1.18	1.09/ .59
	HIGHEST	6.88/5.68	2.50/3.5	.076/.052	"	"	.549/	.042/.041	.012/.026	3.82/3.03	3.24/1.87
STERN QUARTER (3.4 FT)	H 1/10	4.07/3.98	2.17/2.13	.084/.093	"	"	.422/.351	.040/.04	- /.022	2.20/2.28	2.48/2.52
	H 1/3	3.17/3.00	1.70/1.59	.074/.073	"	"	.304/.260	.032/.031	.013/.019	1.76/1.80	1.92/1.96
	RMS	2.26/2.13	1.21/1.14	.063/.050	"	"	.211/.181	.024/.023	.011/.014	1.28/1.30	1.36/1.35
	MEAN	2.01/1.87	1.07/1.01	.062/.044	"	"	.177/.157	.022/.022	.011/.014	1.17/1.17	1.20/1.16
	HIGHEST	5.55/6.24	3.22/3.71	.098/.126	"	"	1.223/.809	.062/.05	.014/.022	2.94/3.45	3.32/3.59
FOLLOWING (3.4 FT)	H 1/10	4.67/4.09	1.36/1.63	.029/.048	"	"	.352/.275	.034/.032	.015/ -	4.20/3.39	1.13/1.67
	H 1/3	3.71/3.31	1.11/1.42	.024/.29	"	"	.242/.204	.028/.026	.014/.014	3.37/2.45	.93/1.37
	RMS	2.60/2.33	.83/1.02	.018/.22	"	"	.184/.145	.021/.020	.012/.012	2.33/2.22	.65/ .98
	MEAN	2.29/2.08	.77/ .93	.018/.19	"	"	.146/.129	.020/.019	.012/.012	2.00/1.08	.59/ .88
	HIGHEST	5.52/5.30	1.64/1.91	.037/.067	"	"	1.508/.467	.039/.044	.015/.014	6.77/5.13	1.55/2.19

* (SWH) = Significant Wave Height
\- Data not available because fewer than ten peaks in record exceeded the defined epsilon limit.

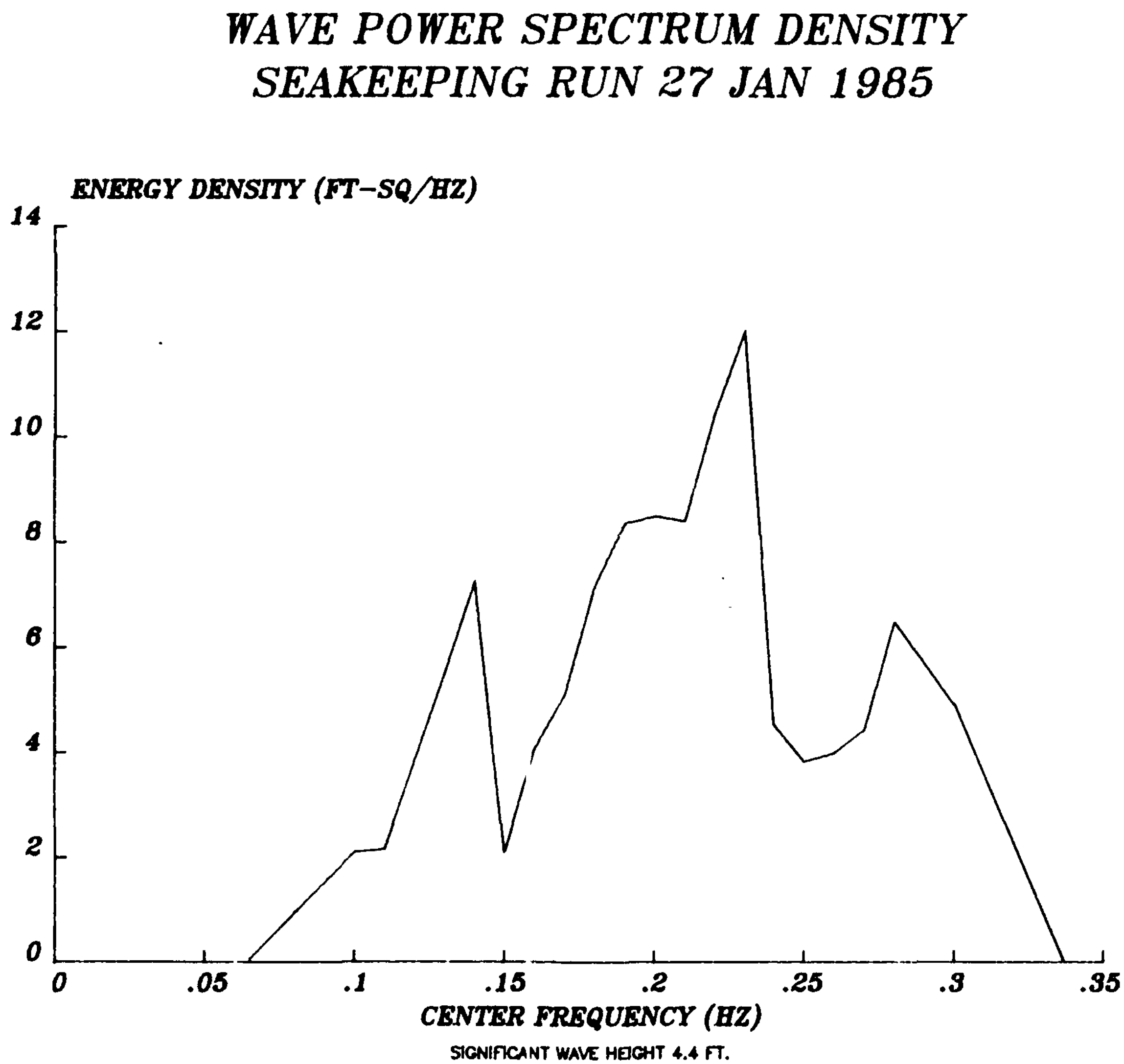


FIGURE B-XIX WAVE PSD PLOT, 4.4 FT. SEAS, 27 JAN 85

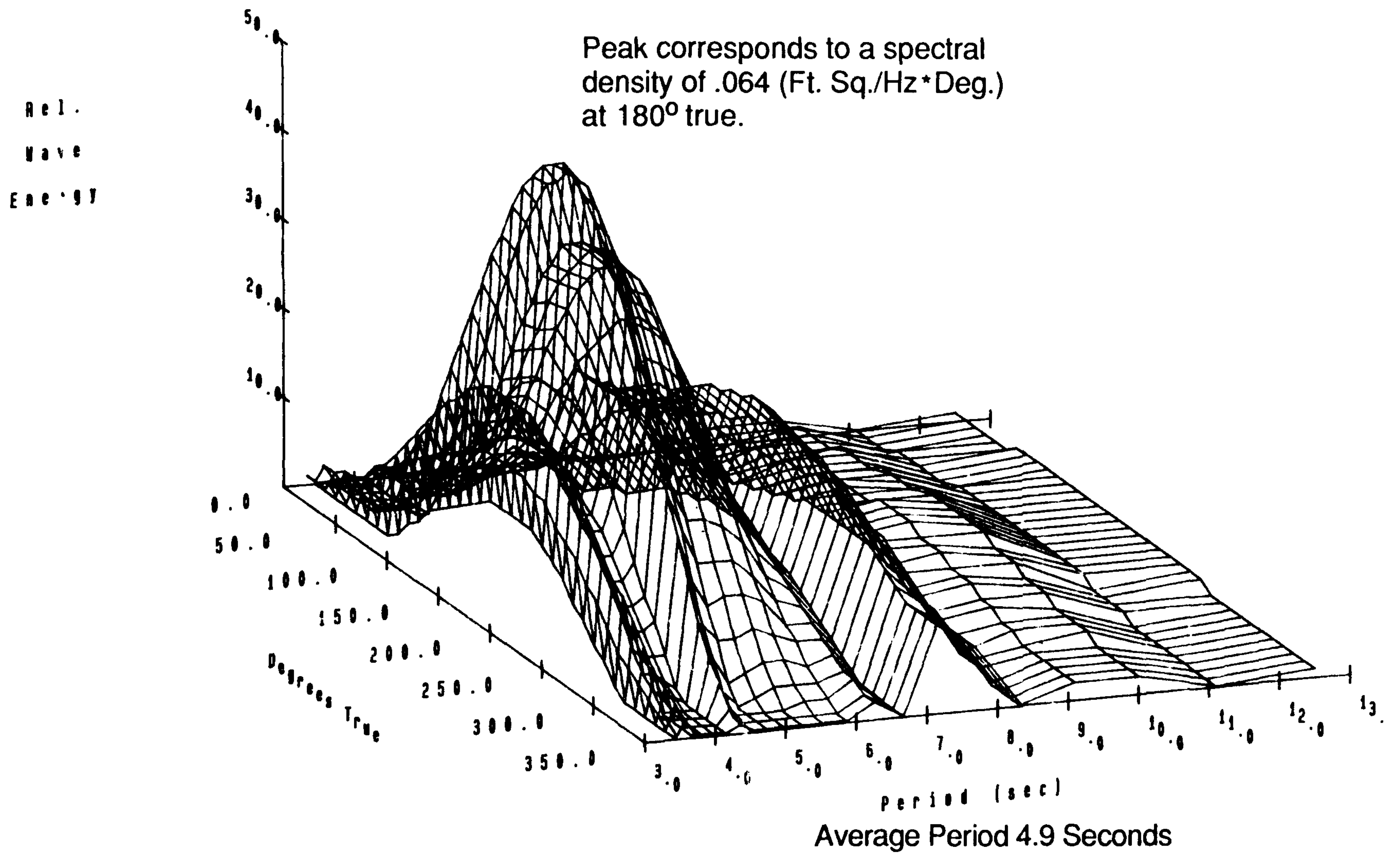


FIGURE B-XX 3-D DIRECTIONAL WAVE PLOT, 4.4 FT. SEAS, 27 JAN 85

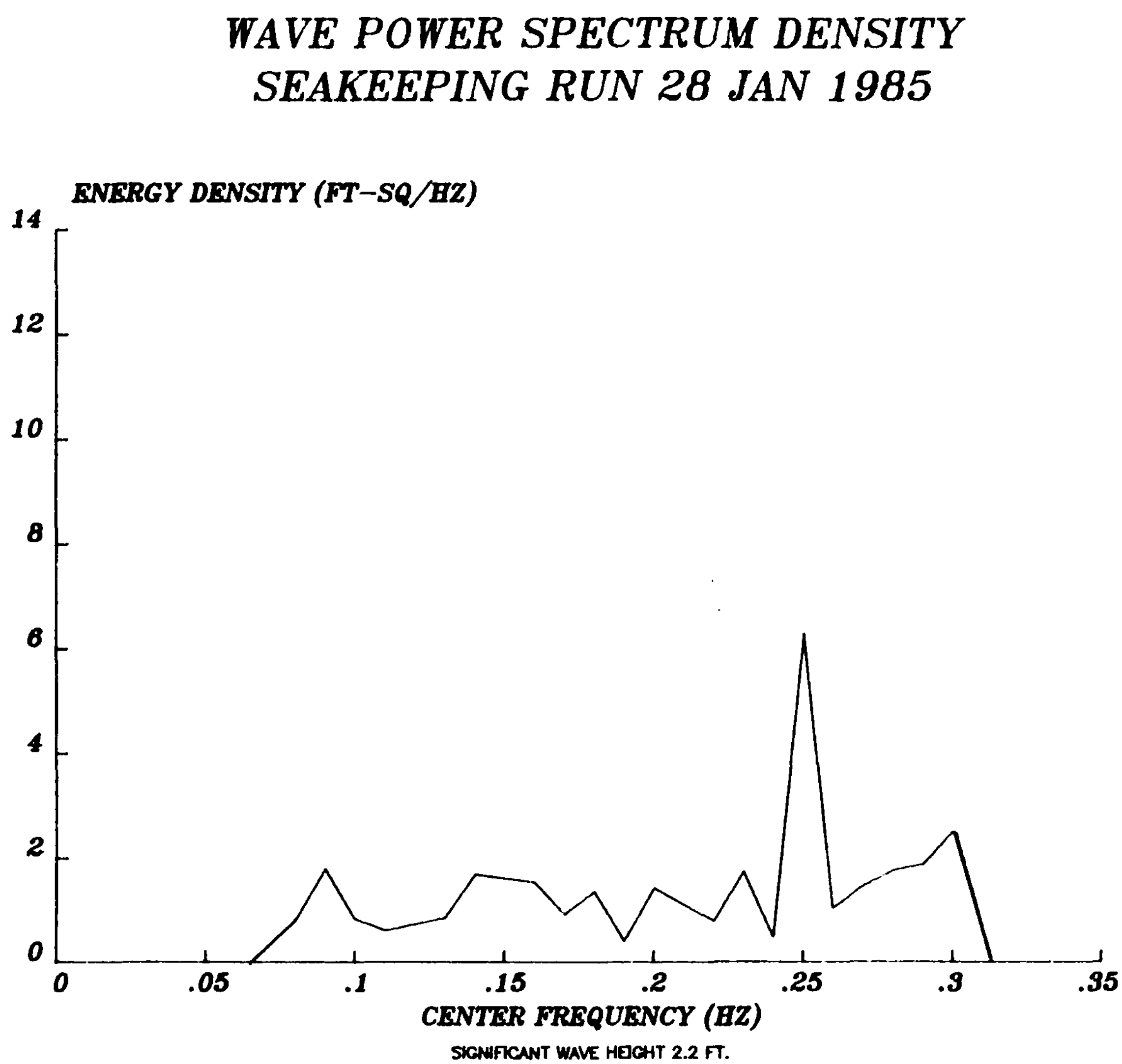


FIGURE B-XXI WAVE PSD PLOT, 2.2 FT. SEAS, 28 JAN 85

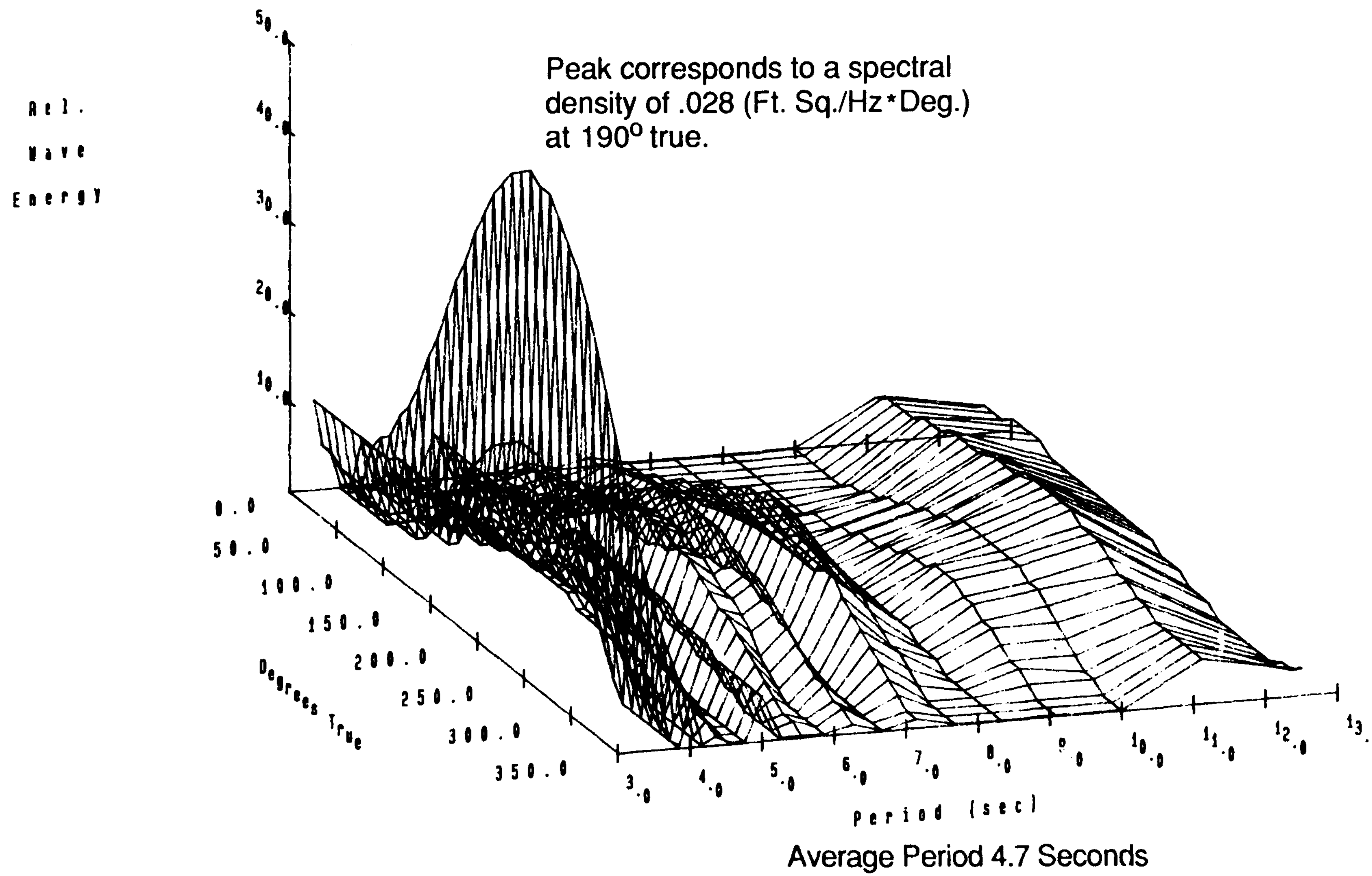


FIGURE B-XXII 3-D DIRECTIONAL WAVE PLOT, 2.2 FT. SEAS, 28 JAN 85

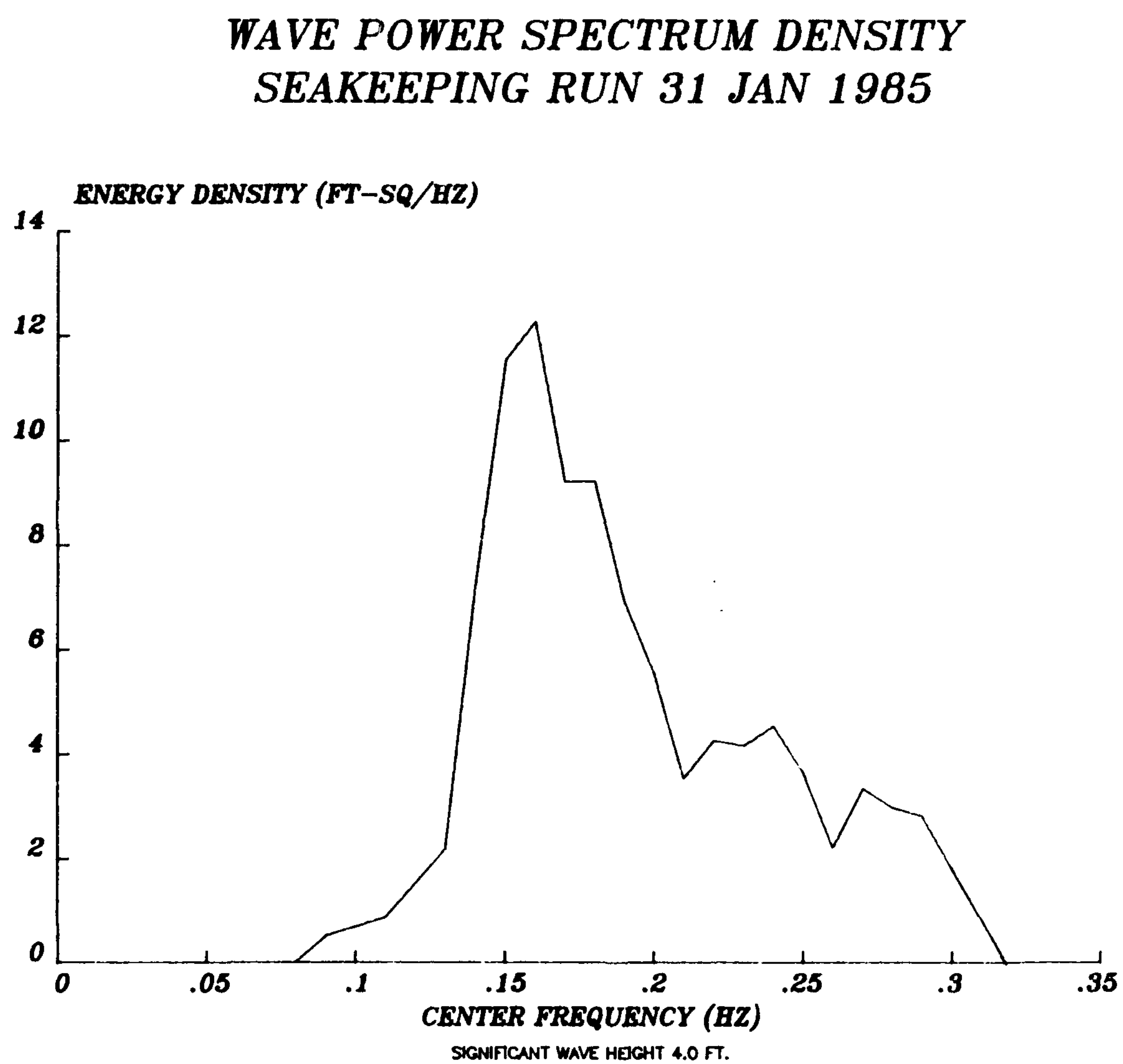


FIGURE B-XXIII WAVE PSD PLOT, 4.0 FT. SEAS, 31 JAN 85

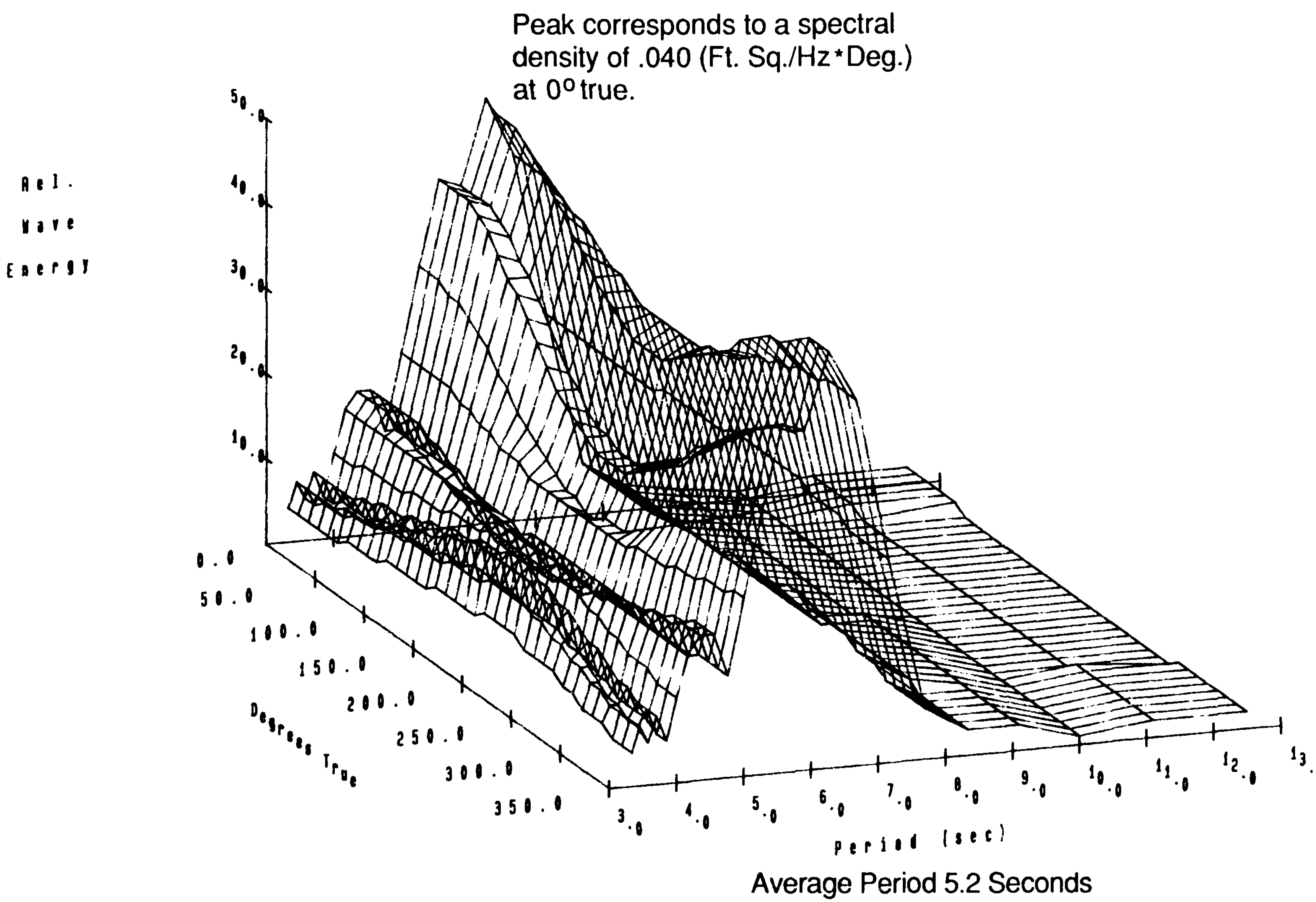


FIGURE B-XXIV 3-D DIRECTIONAL WAVE PLOT, 4.0 FT. SEAS, 31 JAN 85

WAVE POWER SPECTRUM DENSITY
SEAKEEPING RUN 31 JAN 1985

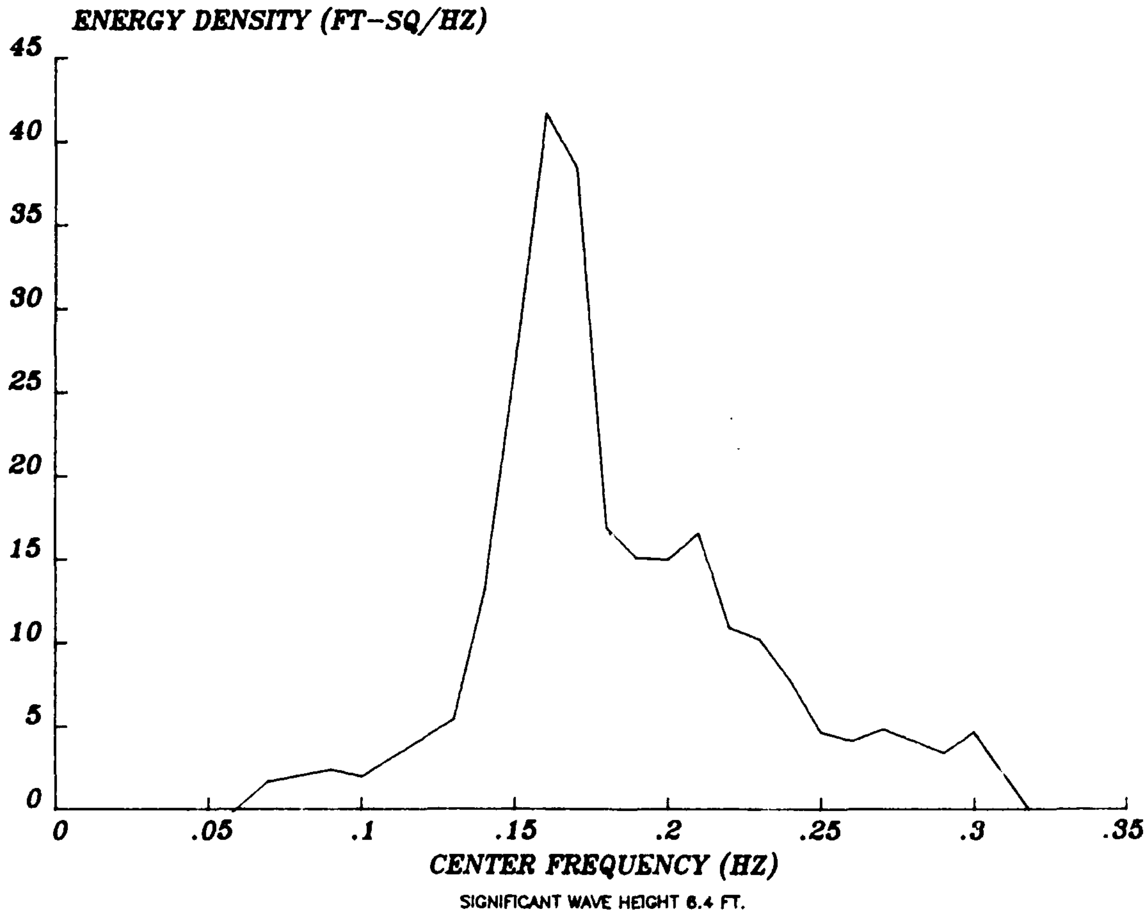
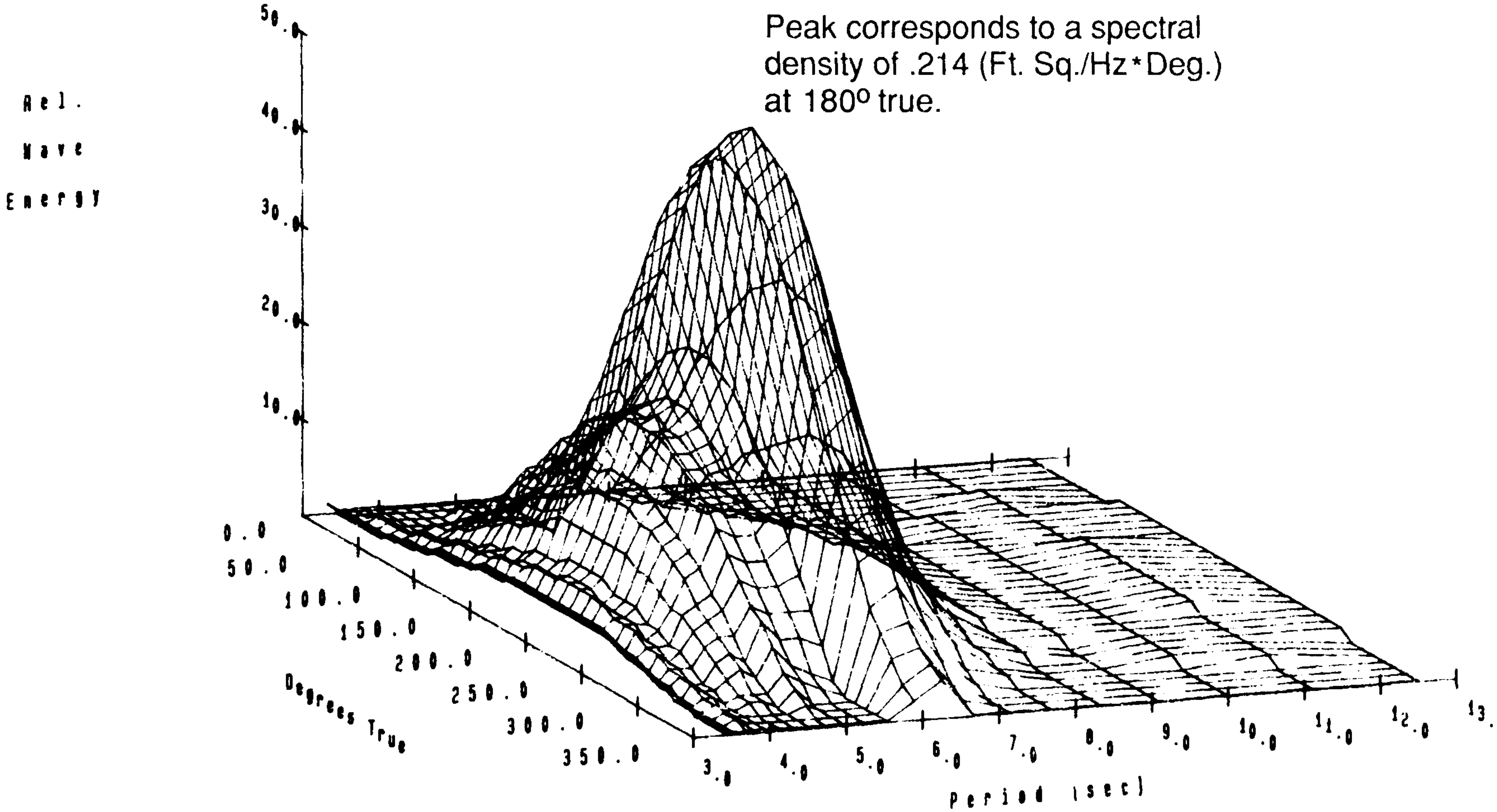


FIGURE B-XXV WAVE PSD PLOT, 6.4 FT. SEAS, 31 JAN 85



Average Period 5.5 Seconds

FIGURE B-XXVI 3-D DIRECTIONAL WAVE PLOT, 6.4 FT. SEAS, 31 JAN 85

WAVE POWER SPECTRUM DENSITY
SEAKEEPING RUN 02 FEB 85

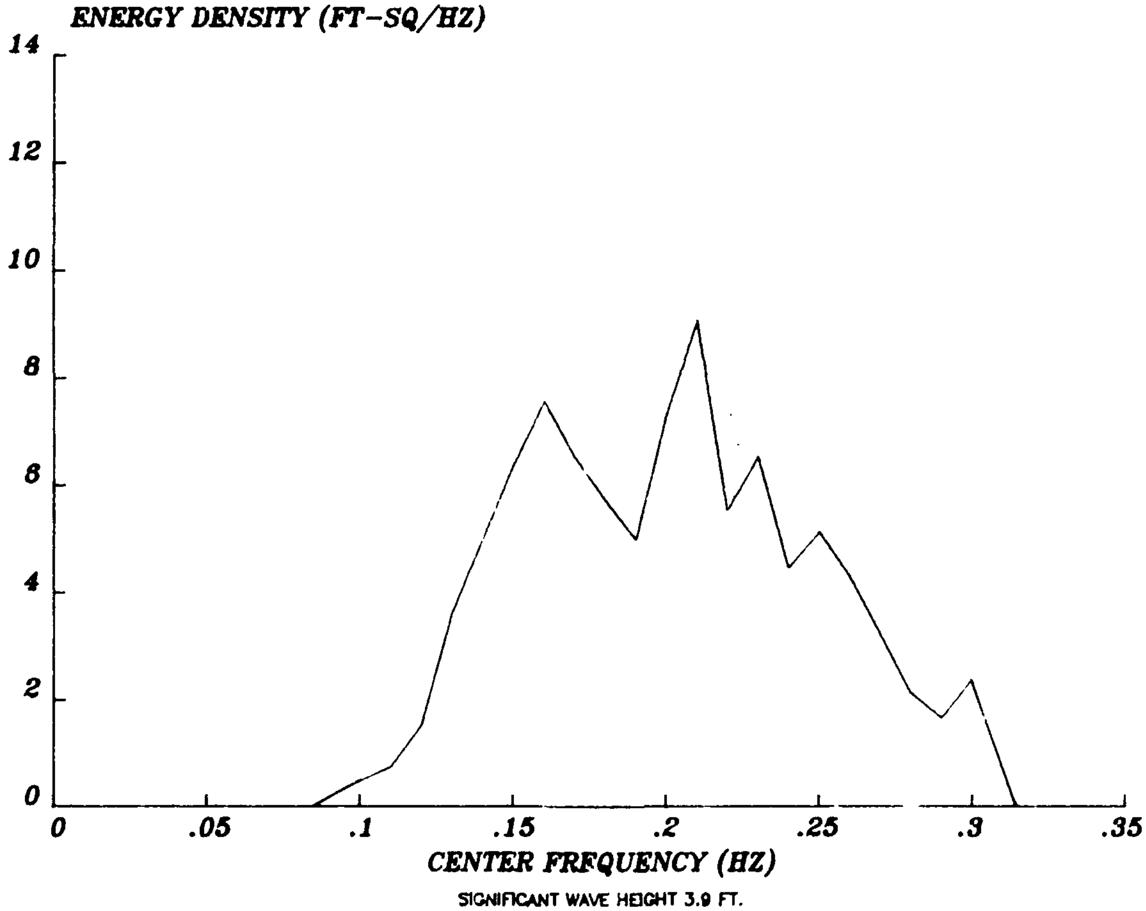


FIGURE B-XXVII WAVE PSD PLOT, 3.9 FT. SEAS, 2 FEB 85

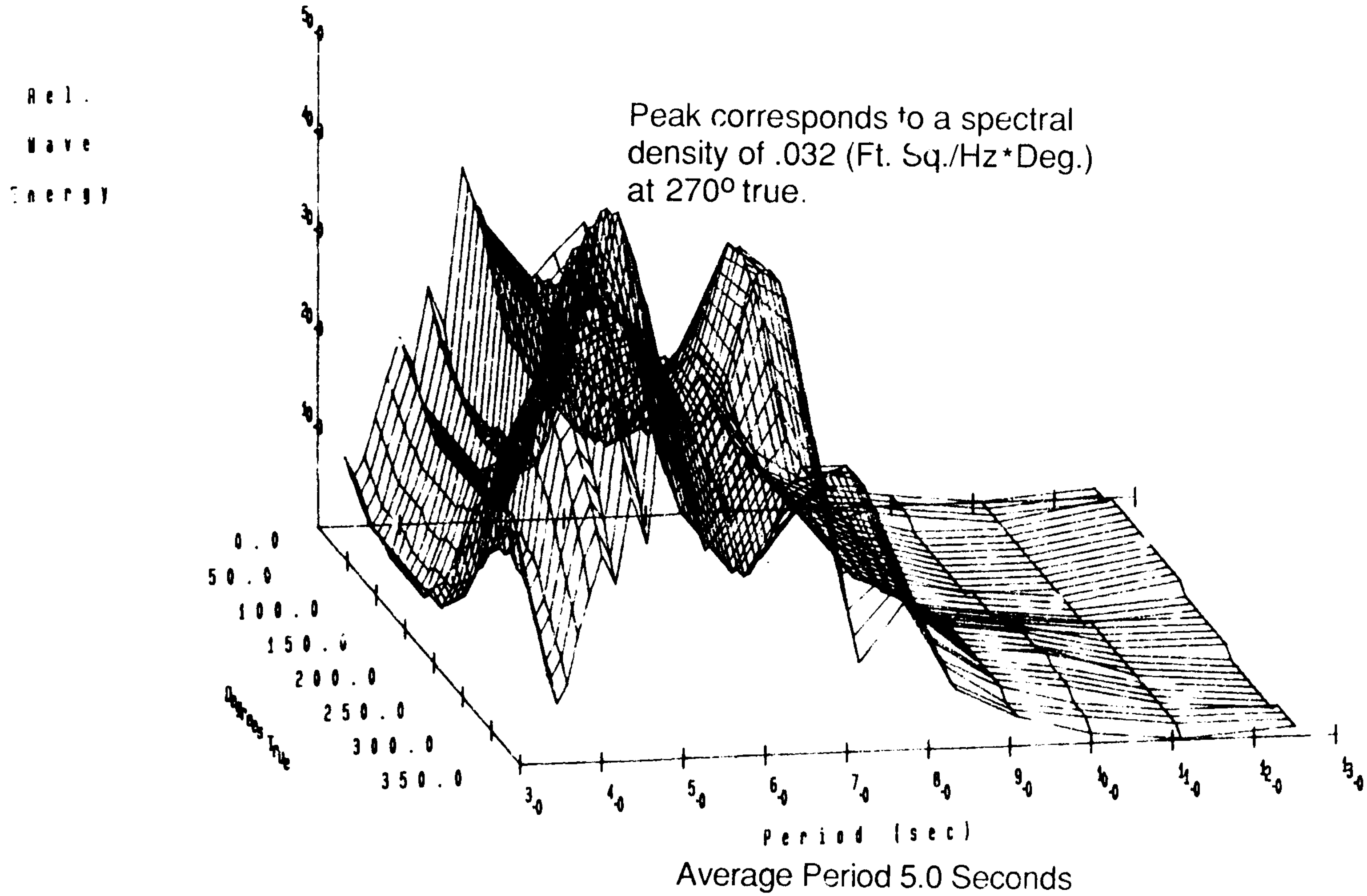


FIGURE B-XXVIII 3-D DIRECTIONAL WAVE PLOT, 3.9 FT. SEAS, 2 FEB 85

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APPENDIX C

NASA RIDE QUALITY MEASUREMENTS ONBOARD COAST GUARD CUTTER SEA HAWK

STRUCTURES DIRECTORATE - LANGLEY RESEARCH CENTER

PRELIMINARY INFORMATION REPORT

PIR NO.: SD-5

TITLE: NASA Ride Quality Measurements Onboard Coast Guard Vessel Seahawk

AUTHOR: Dr. Jack D. Leatherwood

ORGANIZATION: Acoustics Division
Structural Acoustics Branch

DATE: March 1985

NASA Ride Quality Measurements Onboard Coast Guard Vessel Seahawk

Background

At the request of the U.S. Coast Guard Research and Development Center, Avery Point, Groton, CT, NASA personnel participated in tests of a 110-foot Surface Effect Ship (Seahawk) at Key West, Florida during the week of January 29 - February 1, 1985. Specific purposes of NASA involvement were to (1) utilize the NASA ride quality meter to obtain detailed measurements of passenger ride quality for comparison with other ride quality measurement instruments and procedures and (2) to provide a data base for future vessel acquisition and support. Original plans called for the NASA measurements to be made on January 29, 30, and 31. Engine problems prevented acquisition of data on January 29 but extensive data were obtained during vessel operations on January 30 and 31.

Results of the NASA ride quality measurements are presented and discussed in the remaining sections of this writeup. Consideration is limited to examination of the various subjective discomfort indices output by the meter. The physical vibration and noise parameters output by the meter are given in the accompanying tables but are not directly addressed. First, however, a brief discussion of the basic concepts embodied within the NASA meter is given in order to facilitate understanding of the various parameters provided as routine output by the meter.

Description of Ride Quality Meter

The NASA ride quality meter is a direct implementation of a comprehensive comfort algorithm developed at Langley Research Center. More than 3,000 people rode in the Langley Ride Quality simulator where they were exposed to

controlled combinations of vehicle vibration and noise. Each completed a questionnaire detailing the level of discomfort experienced. These data provided the basis for development of a computer model, which transforms individually measured vibration/noise elements into subjective comfort units, then combines the subjective units to produce an overall discomfort index that typifies passenger comfort within the total vibration/noise environment. It is this computer model that is directly implemented within the ride quality meter.

The meter consists of sensing elements to measure vibration in five axes (vertical, lateral, longitudinal, roll, and pitch) and interior noise. The vibration and noise data are frequency-weighted in accordance with the specialized and detailed psychophysical functions that define human response to noise and vibration. These functions were determined during the course of the NASA research. The frequency-weighted noise and vibration data are then applied to the NASA comfort algorithm which outputs via, an internal printer, the following subjective discomfort indices:

DTOT - Total subjective discomfort index, a single index incorporating the effects of multiple frequency, multiple axis vibrations and vehicle interior noise

DVIB - Subjective discomfort due to the vibration environment

DN - Subjective discomfort due to the noise within the combined noise and vibration environment

DIN - Subjective discomfort due to noise if vibration is absent (DVIB = 0)

(NOTE: DTOT = DVIB + DN)

DLONG - Subjective discomfort due to longitudinal axis vibrations

DPITCH - Subjective discomfort due to pitch axis vibrations

DROLL - Subjective discomfort due to roll axis vibrations

DLAT - Subjective discomfort due to lateral axis vibrations

DVERT - Subjective discomfort due to vertical axis vibrations

Additional printer outputs are the weighted rms acceleration levels (GLONG, GPITCH, GROLL, GLAT, GVERT) and the subjective discomfort indices due to each of six octave bands (63, 125, 250, 500, 1000, 2000 Hz) of noise.

Interpretation of the absolute levels of subjective discomfort output by the meter relies to some extent upon contextual factors within a given mode of transportation as well as the prior experience and judgements of the ride quality investigators. Extensive measurements made onboard other transport vehicles such as helicopters, trucks, automobiles, and railcars have indicated that the transition between a comfortable and uncomfortable ride usually occurred at subjective discomfort levels between approximately 2 to 2.5 subjective units. Whether or not the above guidelines apply to the shipboard environment is uncertain and subject to future confirmation. For comparative evaluations of ride quality, however, absolute levels of the subjective indices are not of concern and direct, reliable assessments of relative ride quality within and between vessels can be readily made.

It is also important to note that the NASA discomfort indices do not reflect the influence of vibration energy at frequencies that produce motion sickness. The ranges of vibration frequencies for which the NASA comfort algorithm is applicable are given below.

	Minimum Freq, Hz	Maximum Freq, Hz
Vertical	1	30
Lateral	.5	10
Longitudinal	.5	6.5
Roll	.5	10
Pitch	.5	6.5
Noise	50	2500

Measurement Procedure

At the direction of the Coast Guard Project Manager the NASA instrumentation was set up within a two-berth compartment located on the mess deck adjacent to the galley area. The five axis accelerometer box was placed on the floor near the forward end of the lower bunk. The microphone was placed about one foot above the top surface of the upper bunk approximately two feet from its forward end. Also located on the upper bunk were the ride quality meter, an audio tape recorder, and a seven channel instrumentation recorder. These recorders were used to obtain backup data to be used in the event of ride quality meter failure. At this location the meter was operated almost continuously throughout the tests. The meter was turned off during long stops (e.g., lunch) and to change printer paper when required. On the first day of testing the meter was inadvertantly turned off for 52 minutes. This is noted in Table 1.

Results from Day 1

A summary of the meter output quantities for Day 1 is given in Table 1. This table contains approximately one-fourth of the meter output for Day 1. Included in the table are the various discomfort indices described earlier as well as the weighted root-mean-square acceleration levels for each axis of vibration. The left-most columns contain the numbered ride conditions and elapsed meter time (measured from initial turn on and subsequent meter resets to zero time). Each discrete time is arbitrarily defined as a ride condition and provides a convenient parameter for subsequent plotting of the data. This is particularly useful since information required to relate meter events (e.g., time) to specific test and/or operating conditions was not available at the

time of measurement. Thus, the discussion and comments that follow, as well as implications derived from these results, must be treated as objective observations base upon examination of the "face value" of the data. No attempt is made to explain fluctuations and/or trends in the data or to account for the significant differences between the results of Day 1 and Day 2 (to be discussed later). This is left up to the cognizant Coast Guard test personnel familiar with the actual conditions under which these results were obtained.

The meter output parameter that typifies overall human subjective comfort response is the total discomfort index, DTOT. This parameter is plotted in Figure 1 for each of the ride conditions of Table 1. Also shown in Figure 1 is the noise discomfort index, DN, which represents the contribution of noise to the total discomfort index. (Since DTOT = DVIB + DN, the difference between the two curves in figure 1 is the vibration contribution to total discomfort). These data indicate that human comfort response within the measured environments is influenced most by the vibration components of the environments. It is also evident that total measured discomfort varied considerably over the range of ride conditions on Day 1. Highest levels of discomfort were obtained during cruise away from the harbor (rides 4-14) and return to the harbor (rides 50-71). The least discomfort occurred during turning maneuvers (rides 15-31) and during the stop for lunch (rides 38-44).

Recall that the measurement of ride quality within other transport vehicles has indicated that discomfort threshold generally corresponded to discomfort values between 2.0 and 2.5. Using this range as a tentative guideline, it was found that 38 of the 71 ride conditions would be classified as uncomfortable, with the degree of discomfort increasing as the value of the discomfort index increases. Examination of Figure 1 may also give the impression that the noise

component of discomfort would be totally acceptable for all ride conditions. This, however, would be erroneous. The reason for this is due to a fundamental interaction between noise and vibration discovered in the course of the NASA ride quality research and incorporated in the comfort algorithm. The nature of this interaction is such that the noise contribution to total subjective discomfort depends upon the level of vibration simultaneously present in the environment. This means that, for a given level of noise, the noise discomfort index will be greater for an environment with low vibration than for an environment having high levels of vibration. This is important since it means that reducing vibration alone will not necessarily solve a ride quality problem since the crew and/or occupants then pay more attention to the noise. To assess this effect the ride quality meter provides an additional output (DIN) which is the noise discomfort index that would occur if vibration were totally eliminated from the environment. In this case the noise discomfort index would be identical to the total discomfort index (i.e., DTOT = DIN when DVIB = 0). This index is presented in Figure 2 for comparison with the actual noise discomfort indices measured in the presence of vibration. This comparison implies that, even if vibration could be greatly reduced (by a ride control system, for example), the noise discomfort would increase for many of the ride conditions so that, in many instances, the ride environment would still be only marginally acceptable. Achievement of an acceptable environment would require that measures also be taken to control noise transmission into the interior environment. The ability to provide this type of ride assessment is one of the more powerful features of the ride quality meter.

A detailed examination of the effects of individual axes of vibration on the measured discomfort response for Day 1 is presented in Figure 3. Shown in

this figure is the vibration discomfort index, DVIB, and the relative values of the single axis discomfort indices from which DVIB is derived. Only the vertical, lateral, and roll vibration discomfort indices are presented since the pitch and longitudinal discomfort indices were relatively small (see Table 1). These data indicate that roll axis vibration was the dominant contributor to vibration discomfort for many of the ride conditions (4-14, 32-37, 57-71) and had the least influence at other ride conditions (16-31 and 38-44). Vertical axis vibration generally was the second largest contributor to vibration discomfort followed by the lateral vibration component. Both the vertical and lateral discomfort components exhibited less fluctuation between ride conditions than did roll discomfort. As will be discussed later these results are somewhat different from those obtained on Day 2. Explanation of the fluctuations of the data in Figure 3 and the relative levels of the several discomfort indices must await subsequent analysis of the physical vibration data and identification of the ride conditions by the Coast Guard.

Results from Day 2

The meter output quantities for Day 2 measurements are given in Table 2. A total of 69 ride conditions are given which cover a total test duration of approximately 7 hours. The data presented in Table 2 represents about one-seventh of the meter data obtained and is representative of the discomfort history for the Day 2 testing. The total discomfort index, DTOT, and noise discomfort index, DIN, are plotted in Figure 4 for each of the ride conditions of Table 2. These data indicate that total discomfort remained relatively constant throughout the test and generally did not reach the peak levels attained on Day 1 (see Figure 1). The pronounced dips in DTOT represent measurements made when the vessel was dead in the water. Comparison of Day 2

and Day 1 results also shows that the discomfort due to noise was higher on Day 2. This is likely due to the noise/vibration interaction described earlier and not to a significant increase in interior noise level. If the vibration levels could be reduced to zero then the noise discomfort index would take on the marginally acceptable values represented by the open symbols of Figure 5. This further illustrate that reduction of vibration only may not be sufficient to achieve acceptable crew ride comfort.

The various vibration discomfort components for Day 2 that most influenced ride comfort are illustrated in Figure 6. These results differ from those of Day 1 (Figure 3) in several aspects. These include:

(a) Vibration discomfort for Day 2 did not attain the high levels measured on Day 1.

(b) The dominant component of vibration discomfort for Day 2 was vertical vibration. One Day 1 (see Figure 3) the dominant discomfort component was roll vibration.

(c) Roll discomfort on Day 2 varied only slightly over the various ride conditions as compared to the large fluctuations in roll discomfort observed on Day 1.

(d) The lateral component of vibration discomfort for Day 2 was similar to that measured on Day 1.

Explanation of the difference between Day 1 and Day 2 discomfort measurements must await future evaluation of the physical ride data by the Coast Guard.

Summary Comments

It has been seen that the NASA ride quality meter provided a variety of output parameters characterizing passenger comfort within the SES environment. Many of these parameters are unique in that they represent subjective indices of comfort and hence permit direct identification of the particular physical parameters of the environment that most contribute to passenger discomfort. This is not always apparent from analysis of physical noise and vibration factors alone. The ultimate usefulness and/or applicability of the NASA discomfort indices in the evaluation of shipboard ride quality is a matter that must be decided by the Coast Guard after careful correlation of the data contain herein with the physical data characterizing the operating conditions throughout the tests.

RIDE QUALITY MEASUREMENTS - SEAHAWK

(DAY 1)

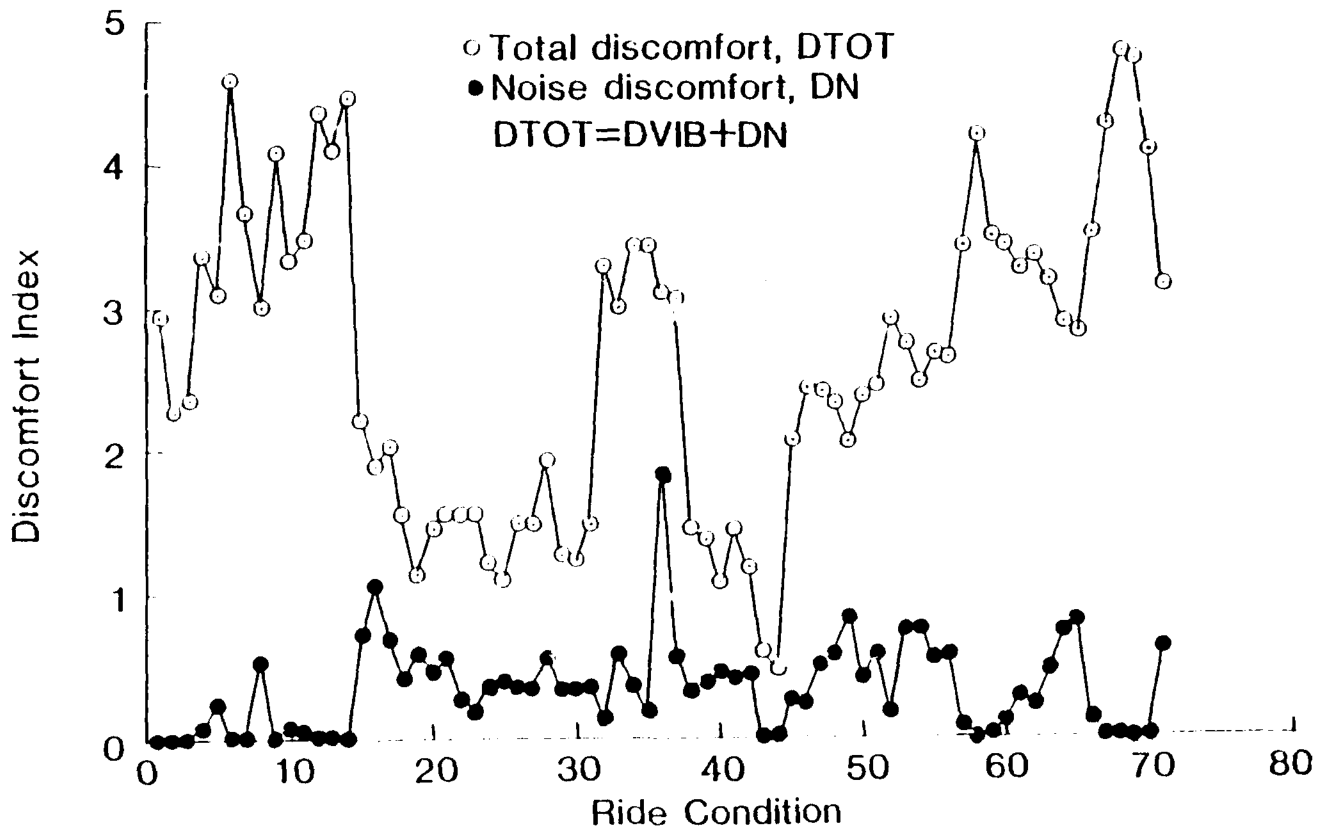


FIGURE 1

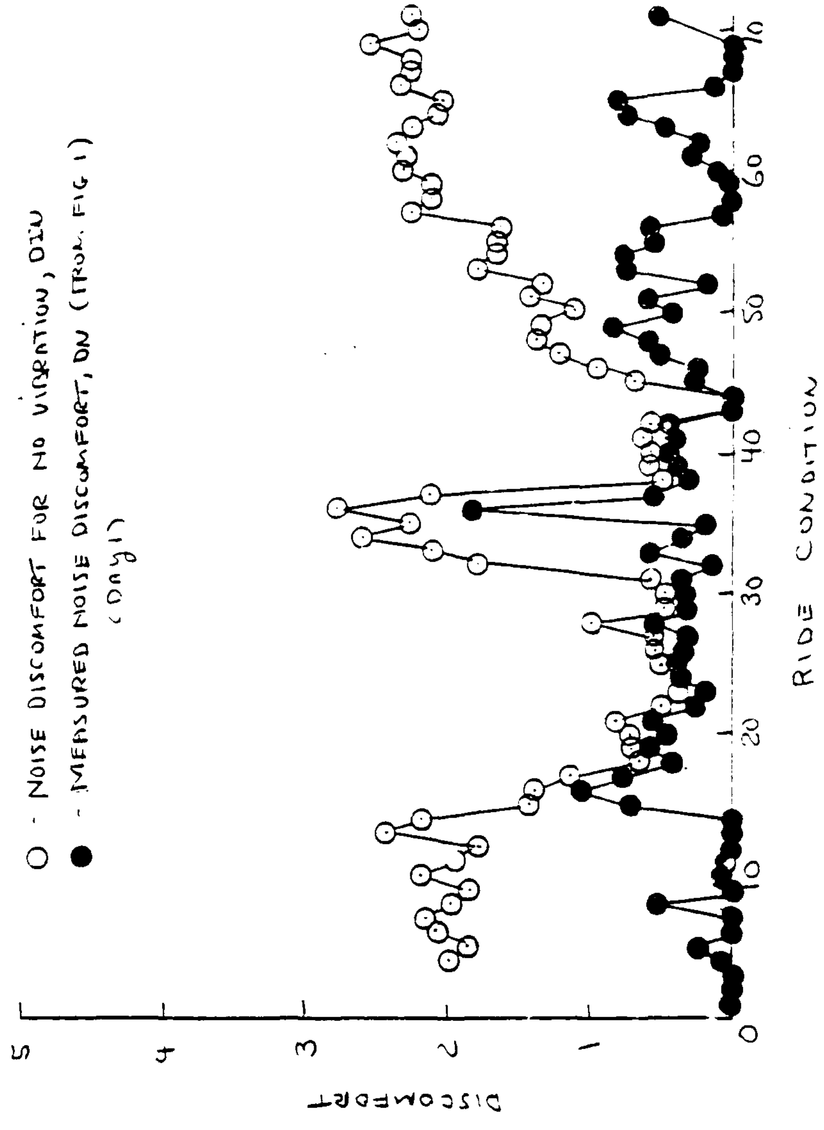
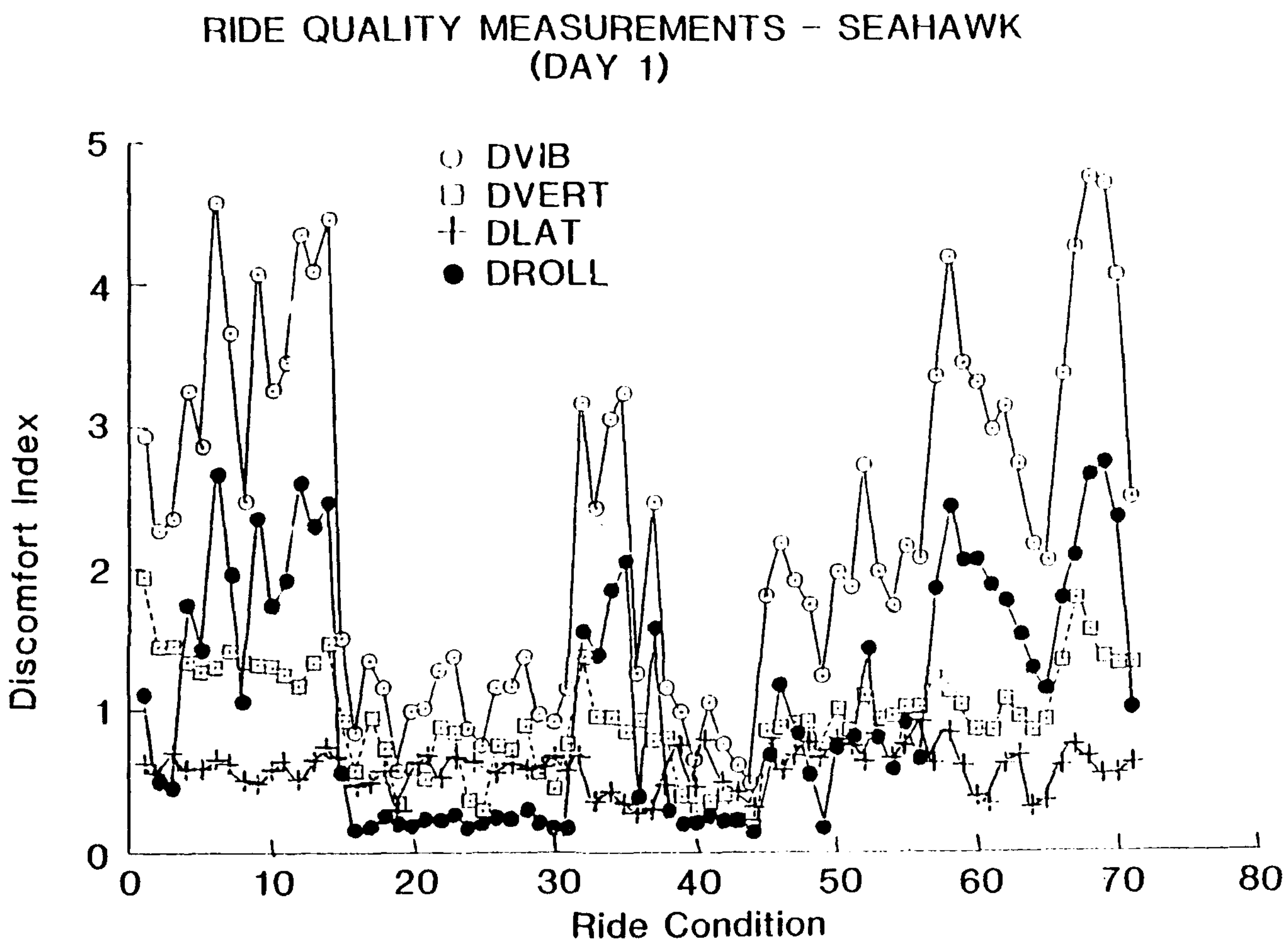

○ - NOISE DISCOMFORT FOR NO VIBRATION, DIU
● - MEASURED NOISE DISCOMFORT, DN (FROM FIG 1) (DAY 1)
DISCOMFORT
0
1
2
3
4
5
10
20
30
40
50
60
70
RIDE CONDITION

FIGURE 2



RIDE QUALITY MEASUREMENTS - SEAHAWK
(DAY 1)
DVIB
DVERT
DLAT
DROLL
Discomfort Index
0
1
2
3
4
5
0
10
20
30
40
50
60
70
80
Ride Condition

FIGURE 3

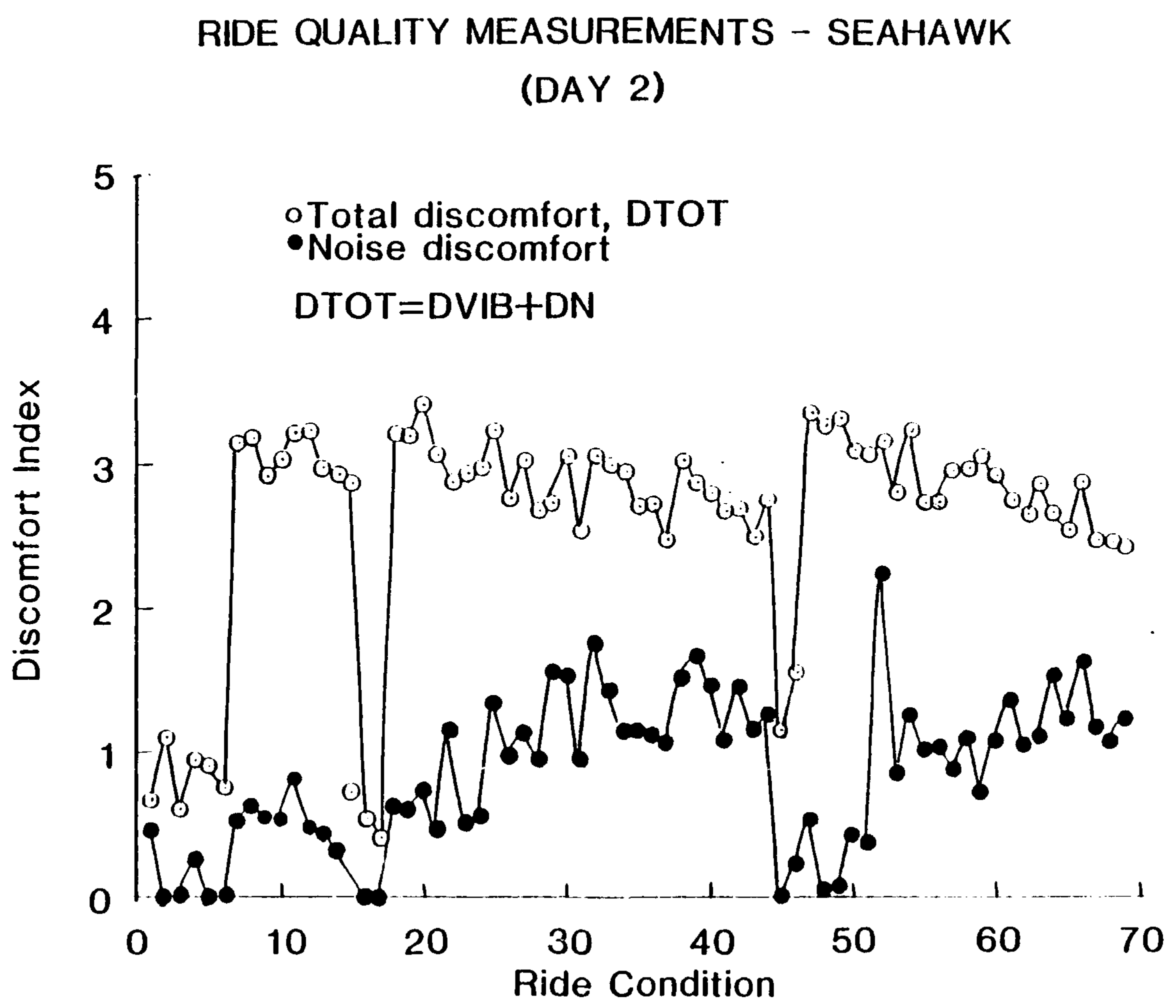

RIDE QUALITY MEASUREMENTS - SEAHAWK
(DAY 2)
oTotal discomfort, DTOT
•Noise discomfort
DTOT=DVIB+DN
Discomfort Index
0
1
2
3
4
5
0
10
20
30
40
50
60
70
Ride Condition

FIGURE 4

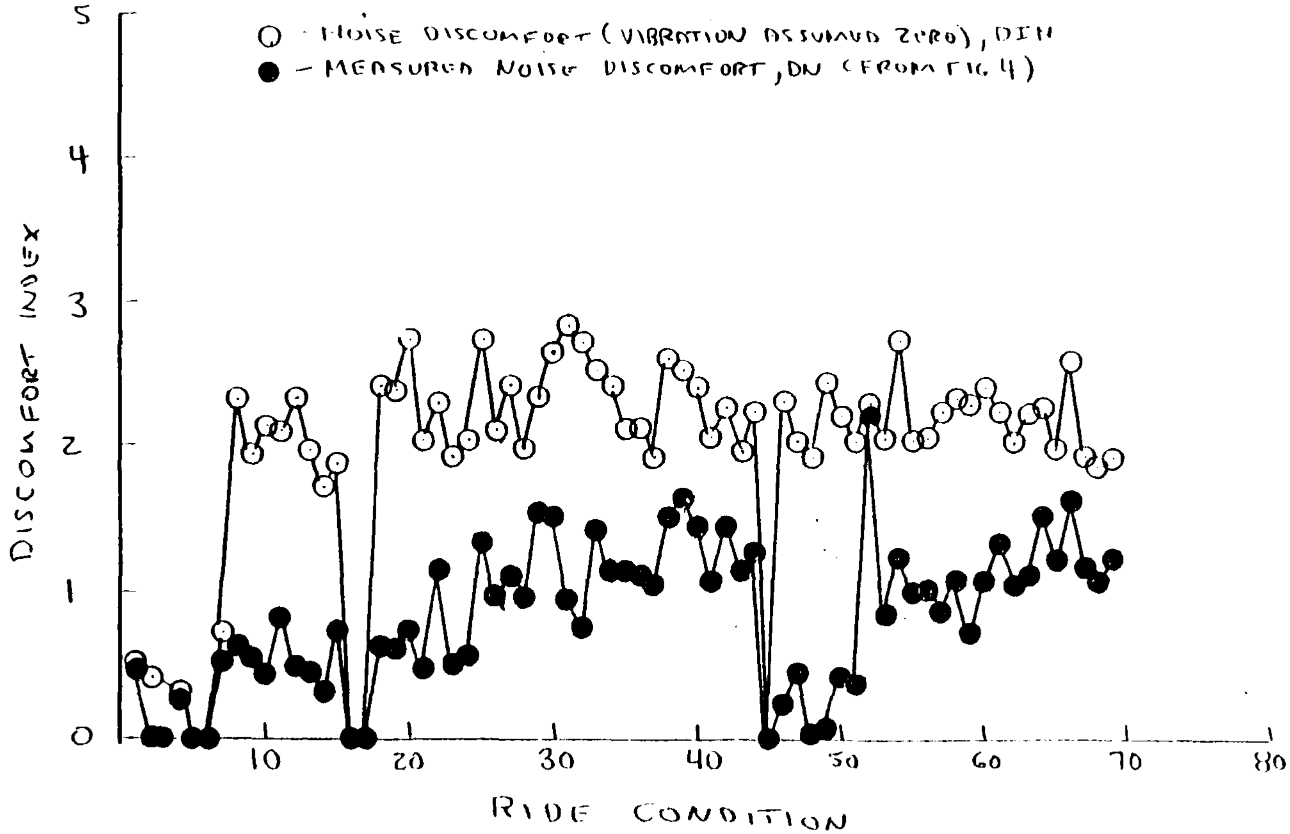

○ - NOISE DISCOMFORT (VIBRATION ASSUMED ZERO), DIN
● - MEASURED NOISE DISCOMFORT, DN (FROM FIG. 4)
DISCOMFORT INDEX
0
1
2
3
4
5
10
20
30
40
50
60
70
80
RIDE CONDITION

FIGURE 5

RIDE QUALITY MEASUREMENTS - SEAHAWK
(DAY 2)

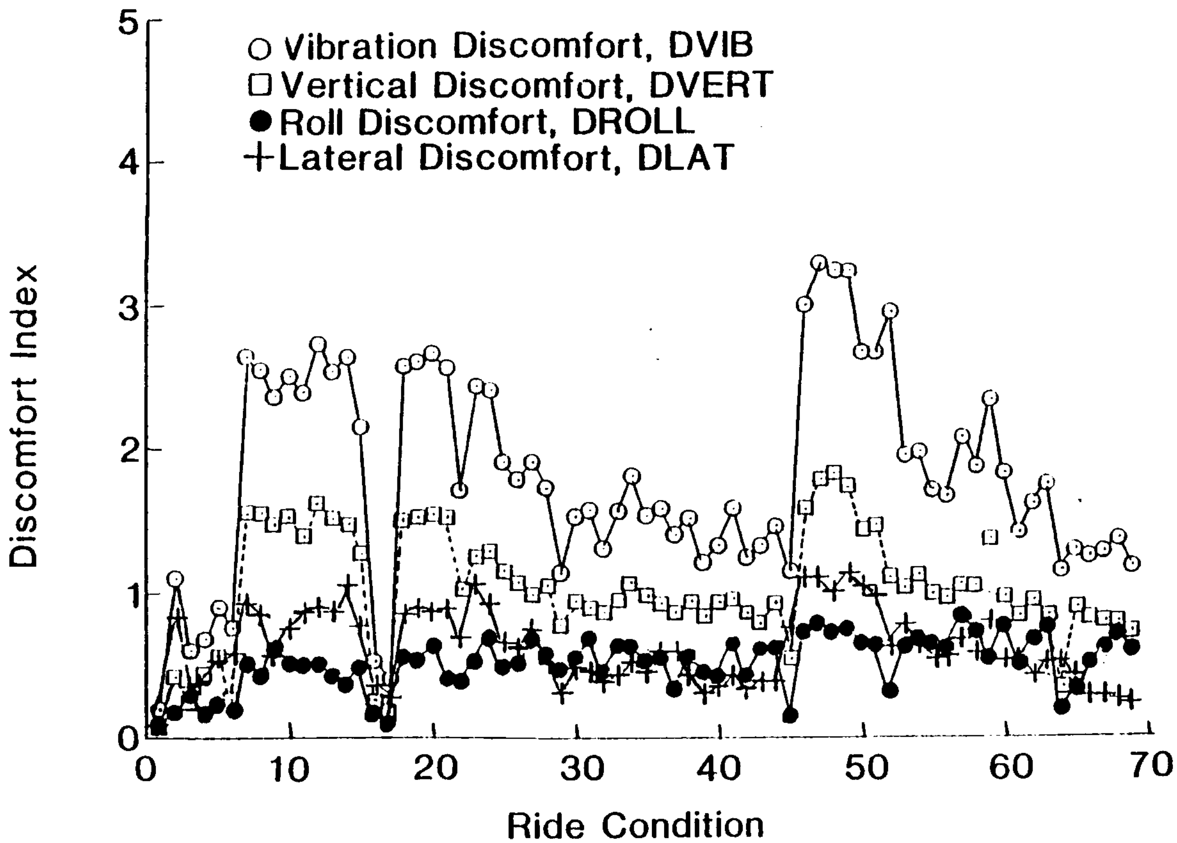


FIGURE 6

TEST DATE : 11/30/85 (DAY 1)

VESSEL: SEAHAWK

TABLE 1
NASA RIDE QUALITY METER MEASUREMENTS

RIDE CONDITION	METER TIME	DISCOMFORT INDICES DTOT	DVIB	DNOISE	DLONG	DPITCH	DROLL	DLAT	DVERT	WEIGHTED RMS ACCELERATION LEVEL GLONG	GPITCH	GROLL	GLAT	GVERT	DIN	COMMENT
1	19:41	2.93	2.93	0	.215	.273	1.108	.627	1.950	[illegible]	.0317	.2726	.0072	.0302		BACKING OUT
2	20:33	2.27	2.27	0	.215	.242	.495	.563	1.454	.0055	.0377	.1564	.0064	.0271		CRUISE OUT OF HARBOR
3	21:25	2.35	2.35	0	.240	.240	.440	.70	1.16	.0061	.0288	.1455	.0080	.0274		
4	22:17	3.34	3.26	.07	.17	.13	1.72	.59	1.32	.0044	.0156	.1274	.0067	.0241	1.97	
5	23:09	3.09	2.86	.23	.17	.17	1.42	.59	1.27	.0045	.0193	.3623	.0067	.0230	1.85	
6	24:01	4.58	4.58	0	.20	.14	2.67	.65	1.30	.0053	.0165	.6386	.0075	.0236	2.07	
7	25:46	3.66	2.66	0	.16	.16	1.95	.62	1.41	.0042	.0180	.4196	.0071	.0261	2.14	
8	26:38	3.00	2.47	.53	.17	.20	1.05	.50	1.32	.0045	.0232	.2786	.0057	.0241	1.97	
9	27:30	4.09	4.09	0	.18	.15	2.36	.49	1.31	.0046	.0177	.5710	.0056	.0238	1.83	
10	28:22	3.32	3.25	.07	.20	.15	1.72	.59	1.30	.0051	.0179	.4280	.0068	.0236	2.19	
11	29:14	3.48	3.45	.03	.19	.16	1.90	.63	1.25	.0047	.0182	.4678	.0072	.0225	1.94	
12	30:06	4.34	4.34	0	.17	.13	2.60	.51	1.17	.0045	.0154	.6234	.0058	.0248	1.78	
13	31:51	4.09	4.09	0	.21	.16	2.30	.66	1.33	.0048	.0159	.5813	.0066	.0267	2.44	
14	33:35	4.45	4.45	0	.25	.20	2.46	.74	1.44	.0054	.0181	.5580	.0076	.0244	2.17	
15	35:19	2.21	1.50	.71	.12	.16	.53	.66	.71	.0063	.0233	.5926	.0085	.0272	1.40	
16	37:04	1.89	.83	1.06	.37	.11	.14	.42	.57	.0028	.0133	.0577	.0047	.0083	1.39	
17	38:49	2.03	1.31	.68	.12	.17	.17	.47	.95	.0032	.0202	.0673	.0054	.0157	1.12	
18	48:44	1.54	1.14	.40	.08	.10	.24	.59	.71	.0034	.0120	.1005	.0068	.0106	.64	TURNS
19	50:28	1.13	.56	.57	.04	.14	.19	.30	.33	.0017	.0018	.0771	.0080	.0070	.70	
20	54:01	1.45	.99	.46	.07	.18	.18	.60	.59	.0022	.0208	.0769	.0067	.0085	.70	
21	55:46	1.55	1.01	.54	.07	.20	.24	.67	.50	.0021	.0238	.1025	[illegible]	[illegible]	.81	
22	57:32	1.54	1.08	.26	.12	.14	.22	.51	.88	.0032	.0161	.0912	.0058	.0142	.48	
23	59:17	1.56	1.38	.18	.12	.32	.26	.67	.82	.0022	.0367	.1036	.0077	.0127	.35	
24	61:02	1.21	.86	.35	.05	.08	.15	.64	.26	.0015	.0094	.0641	.0074	.0052	.35	
25	62:49	1.10	.73	.37	.03	.13	.17	.52	.24	.0012	.0147	.0801	.0040	.0043	.50	

NASA-Langley Form 10 (AUG 1969)

TEST DATE : 1/30/85 (DAY 1)

TABLE 1

NASA RIDE QUALITY

METER MEASUREMENTS

VESSEL: SEAHAWK

RIDE CONDITION	METER TIME	DISCOMFORT INDICES UTOT	DVIB	DNOISE	DLONG	DPITCH	DROLL	DLAT	DVERT	WEIGHTED RMS ACCELERATION LEVEL GLONG	GPITCH	GROLL	GLAT	GVERT	VIN	COMMENT
26	65:42	1.49	1.15	.34	.10	.21	.23	.55	.75	.0027	.0048	.0162	.0062	.0114	.54	CONT. TURNS
27	68:20	1.49	1.16	.33	.10	.11	.22	.61	.71	.0029	.0129	.0932	.0070	.0105	.55	
28	71:51	1.92	1.37	.55	.13	.19	.29	.57	.88	.0036	.0217	.1109	.0066	.0113	.99	
29	75:22	1.27	.95	.32	.06	.23	.19	.58	.54	.0018	.0267	.0778	.0066	.0078	.47	
30	78:54	1.23	.90	.33	.05	.13	.17	.66	.42	.0016	.0151	.0567	.0075	.0060	.47	
31	82:25	1.49	1.15	.34	.10	.15	.17	.58	.75	.0027	.0178	.0688	.0064	.0113	.58	
32	85:57	3.29	3.17	.12	.27	.19	1.54	.68	1.38	.0049	.0215	.2076	.0078	.0255	1.19	
33	87:29	2.99	2.41	.58	.16	.20	1.39	.38	.95	.0041	.0236	.3558	.0043	.0158	2.11	
34	93:01	3.41	3.05	.36	.13	.13	1.84	.42	.94	.0034	.0145	.1558	.0048	.0156	2.60	
35	96:32	3.41	3.22	.19	.11	.13	2.03	.32	.83	.0031	.0153	.1774	.0036	.0132	2.27	
36	100:04	3.07	1.26	1.82	.18	.12	.37	.28	.91	.0016	.0136	.1355	.0032	.0149	2.79	
37	103:37	3.04	2.48	.56	.12	.10	1.56	.27	.77	.0032	.0114	.3736	.0023	.0118	2.12	
38	107:08	1.47	1.16	.31	.12	.19	.28	.17	.77	.0037	.0217	.1073	.0054	.0123	.50	
39	111:40	1.38	.99	.37	.04	.07	.18	.76	.38	.0014	.0080	.0767	.0087	.0055	.58	
40	115:13	1.09	.64	.45	.04	.06	.19	.44	.28	.0013	.0069	.0779	.0051	.0041	.58	
41	118:44	1.46	1.06	.40	.01	.06	.23	.81	.35	.0014	.0060	.0914	.0072	.0050	.62	
42	122:17	1.19	.75	.44	.05	.07	.20	.17	.40	.0016	.0083	.0848	.0056	.0057	.58	
43	126:04	.60	.60	0	.02	.14	.20	.12	.21	.0007	.0065	.0776	.0017	.0027	0	ALL STOP
44	129:35	.48	.48	0	.01	.18	.16	.33	.18						0	STOP
(METER PRINTOUT INTERRUPTED FOR APPROXIMATELY 52 MINUTES OF METER TIME RESET)																METER TIME RESET

NASA-Langley Form 10 (AUG 1969)

TEST DATE : 11/30/85 (DAY 1)

TABLE 1
NASA RIDE QUALITY METER MEASUREMENTS

VESSEL: SEAHAWK

RIDE CONDITION	METER TIME	DISCOMFORT INDICES DTOT	DVIB	DNOISE	DLONG	DPITCH	DROLL	DLAT	DVERT		WEIGHTED RMS ACCELERATION LEVEL GLONG	GPITCH	GROLL	GLAT	GVERT			COMMENT
45	52:50	2.07	1.80	.27	.11	.15	.69	.80	.85		.0030	.0176	.1988	.0072	.0136		.69	METER TIME RESET
46	55:28	2.42	2.18	.24	.11	.19	1.18	.59	.88		.0031	.0225	.3072	.0068	.0142		.96	
47	59:00	2.10	1.90	.50	.15	.13	.81	.69	.90		.0029	.0504	.2268	.0080	.0148		1.21	
48	62:33	2.31	1.72	.59	.18	.19	.53	.78	.90		.0047	.0216	.1634	.0090	.0147		1.37	
49	66:05	2.05	1.22	.83	.09	.13	.16	.64	.76		.0026	.0149	.0647	.0073	.0115		1.35	
50	68:44	2.38	1.97	.41	.15	.13	.71	.78	1.00		.0039	.0152	.2044	.0090	.0170		1.10	
51	0	2.45	1.86	.59	.09	.20	.81	.75	.81		.0027	.0237	.2264	.0086	.0134		1.41	METER TIME RESET
52	2:39	2.90	2.72	.19	.16	.12	1.13	.63	1.10		.0042	.0137	.2624	.0078	.0193		1.32	
53	6:11	2.72	1.97	.75	.14	.12	.80	.80	.92		.0037	.0144	.2232	.0072	.0151		1.79	
54	9:43	2.47	1.71	.76	.15	.15	.59	.66	.95		.0040	.0171	.1785	.0075	.0157		1.64	
55	13:15	2.68	2.14	.54	.13	.12	.90	.76	1.01		.0036	.0133	.2472	.0088	.0172		1.65	
56	16:47	2.64	2.07	.57	.15	.13	.66	.92	1.01		.0027	.0153	.1935	.0110	.0171		1.63	
57	21:12	3.41	3.34	.07	.21	.18	1.84	.62	1.21		.0052	.0204	.1580	.0071	.0216		2.26	
58	25:37	4.19	4.19	0	.19	.16	2.42	.84	1.13		.0030	.0189	.5813	.0066	.0198		2.11	
59	30:02	3.47	3.44	.03	.15	.13	2.02	.61	1.02		.0040	.0145	.4955	.0070	.0175		2.11	
60	34:27	3.41	3.30	.11	.08	.07	2.06	.31	.86		.0024	.0083	.5038	.0044	.0138		2.31	
61	38:52	3.27	2.98	.29	.08	.09	1.86	.33	.85		.0032	.0100	.1565	.0038	.0137		2.30	
62	43:17	3.34	3.12	.22	.16	.12	1.76	.63	1.07		.0041	.0151	.1575	.0072	.0166		2.37	
63	47:41	3.18	2.71	.47	.15	.13	1.51	.67	.79		.0031	.0146	.2830	.0079	.0154		2.26	
64	52:07	2.88	2.16	.72	.14	.12	1.29	.31	.84		.0026	.0137	.3338	.0085	.0153		2.08	
65	56:32	2.82	2.62	.80	.16	.13	1.13	.36	.71								2.09	

NASA-Langley Form 10 (AUG 1969)

TEST DATE : 1/30/85 (DAY 1)

VESSEL: SEAHAWK

TABLE 1
NASA RIDE QUALITY METER MEASUREMENTS

Page 4 of 4

RIDE CONDITION	METER TIME	DISCOMFORT INDICES DTOT	DVIB	DNOISE	DLONG	DPITCH	DROLL	DLAT	DVERT		WEIGHTED RMS ACCELERATION LEVEL GLONG	GPITCH	GROLL	GLAT	GVERT		DIN	COMMENT
66	60:57	3.50	3.38	.12	.22	.15	1.79	.60	1.34		.0057	.0179	.4436	.0068	.0245		2.34	
67	65:22	4.26	4.26	0	.21	.15	2.09	.75	1.72		.0055	.0176	.5100	.0086	.0345		2.26	
68	69:47	4.76	4.76	0	.21	.15	2.65	.67	1.56		.0054	.0181	.6343	.0077	.0295		2.26	
69	74:12	4.70	4.70	0	.26	.13	2.44	.53	1.38		.0052	.0156	.6552	.0060	.0254		2.56	
70	78:37	4.08	4.08	0	.24	.15	2.34	.55	1.31		.0060	.0180	.5666	.0063	.0238		2.20	
71	81:16	3.12	2.50	.62	.20	.15	1.00	.63	1.33		.0053	.0168	.2686	.0072	.0144		2.26	

NASA-Langley Form 10 (AUG 1969)

TABLE 2

TEST DATE : 1/31/85 (DAY 2) NASA RIDE QUALITY METER MEASUREMENTS

VESSEL: SEAHAWK

Page 1 of 3

RIDE CONDITION	METER TIME	DISCOMFORT INDICES DTOT	DVIB	DNOISE	DLONG	DPITCH	DROLL	DLAT	DVERT	WEIGHTED RMS ACCELERATION LEVEL GLONG	GPITCH	GROLL	GLAT	GVERT	DIN	COMMENT
1	1:35	.66	.20	.116	0	.112	.101	.089	.071	.0002	.0165	.0123	.0007	.0010	1.50	
2	32:09	1.10	1.10	0	.029	.125	.179	.816	.408	.0011	.0144	.0712	.0094	.0059	2.40	
3	41:27	.61	.61	0	.017	.130	.296	.356	.234	.0008	.0150	.1122	.0041	.0034	0	
4	68:35	.94	.69	.25	.036	.190	.179	.360	.428	.0013	.0220	.0715	.0041	.0062	.33	
5	70:56	.90	.90	0	.066	.131	.222	.524	.546	.0020	.0152	.0921	.0060	.0077	0	
6	75:21	.75	.75	0	.023	.080	.175	.583	.247	.0010	.0093	.0729	.0067	.0035	0	
7	91:27	3.16	2.65	.51	.213	.355	.497	.724	1.54	.0074	.0412	.1568	.0111	.0289	.71	
8	94:11	3.18	2.56	.62	.305	.197	.420	.815	1.54	.0076	.0228	.1397	.0097	.0291	2.32	
9	98:49	2.91	2.37	.54	.262	.247	.614	.577	1.47	.0066	.0288	.1830	.0066	.0215	1.96	
10	99:40	3.15	2.72	.43	.355	.296	.420	.702	1.72	.0088	.0344	.1377	.0080	.0330	2.16	
11	1:45	3.21	2.40	.81	.280	.191	.496	.874	1.37	.0041	.0221	.1566	.0100	.0256	2.11	METER TIME RESET TO 0
12	5:15	3.22	2.73	.49	.295	.208	.498	.877	1.61	.0074	.0241	.1571	.0106	.0307	2.34	
13	7:38	2.98	2.54	.44	.01	.28	.42	.84	1.51	.0045	.0322	.1394	.0100	.0285	1.98	
14	11:54	2.93	2.63	.30	.31	.27	.36	1.06	1.48	.0085	.0314	.1265	.0140	.0216	1.72	
15	20:10	2.87	2.15	.72	.24	.21	.48	.77	1.27	.0060	.0247	.1542	.0088	.0230	1.89	
16	21:56	.52	.52	0	.02	.07	.11	.35	.25	.0007	.0007	.0578	.0040	.0036	0	
17	28:01	.40	.40	0	.01	.06	.09	.29	.17	.0008	.0068	.0373	.0032	.0021	0	
18	67:55	3.21	2.59	.62	.28	.27	.56	.87	1.50	.0040	.0310	.1744	.0100	.0282	2.42	
19	73:10	3.20	2.60	.60	.30	.29	.53	.40	1.51	.0045	.0336	.1657	.0106	.0282	2.40	
20	74:12	3.41	2.68	.73	.33	.35	.63	.88	1.54	.0081	.0294	.1858	.0102	.0270	2.76	
21	93:23	3.05	2.58	.47	.38	.32	.40	.81	1.52	.0075	.0247	.1357	.0105	.0297	2.05	
22	3:30	2.87	1.71	1.16	.18	.13	.39	.67	1.03	.0047	.0146	.1332	.0079	.0176	2.30	METER TIME RESET TO 0
23	15:07	2.94	2.44	.50	.26	.38	.52	1.04	1.26	.0066	.0138	.1615	.0142	.0229	1.93	
24	20:26	2.97	2.41	.56	.25	.20	.68	.91	1.29	.0063	.0232	.1781	.0108	.0235	2.06	
25	25:47	3.24	1.90	1.34	.22	.41	.48	.64	1.15	.0056	.0479	.1537	.0073	.0203	2.15	

NASA-Langley Form 10 (AUG 1969)

TABLE 2

TEST DATE : 1/31/85 (DAY 2) NASA RIDE QUALITY METER MEASUREMENTS

VESSEL: SEAHAWK

RIDE CONDITION	METER TIME	DTOT	DVIB	DNOISE	DLONG	DPITCH	DROLL	DLAT	DVERT	GLONG	GPITCH	GROLL	GLAT	GVERT	DIW	COMMENT
		DISCOMFORT INDICES								WEIGHTED RMS ACCELERATION LEVEL						
26	30:58	2.76	1.78	.98	.19	.16	.51	.61	1.08	.0050	.0182	.1587	.0070	.0187	2.11	
27	36:14	3.03	1.91	1.12	.15	.12	.68	.75	.99	.0041	.0114	.1977	.0086	.0168	2.44	
28	43:17	2.68	1.72	.95	.18	.15	.58	.51	1.06	.0016	.0171	.1714	.0068	.0182	2.00	
29	48:33	2.72	1.14	1.58	.11	.10	.47	.31	.77	.0030	.0114	.1503	.0036	.0119	2.37	
30	52:58	3.06	1.53	1.53	.19	.16	.54	.48	.94	.0048	.0188	.1673	.0054	.0156	2.66	
31	56:29	2.53	1.58	.95	.11	.11	.69	.46	.90	.0031	.0128	.2004	.0052	.0116	1.85	
32	61:46	3.06	1.31	1.76	.12	.11	.46	.39	.87	.0032	.0122	.1189	.0015	.0137	2.73	
33	65:18	2.99	1.57	1.42	.16	.14	.63	.42	.95	.0092	.0162	.1865	.0018	.0158	2.54	
34	67:56	2.96	1.81	1.15	.20	.18	.62	.52	1.09	.0051	.0204	.1850	.0059	.0170	2.43	
35	72:26	2.70	1.54	1.15	.15	.13	.52	.46	.98	.0040	.0148	.1617	.0052	.0164	2.13	
36	75:51	2.72	1.59	1.12	.13	.13	.55	.60	.92	.0036	.0145	.1675	.0047	.0151	2.15	
37	81:07	2.18	1.10	1.07	.09	.13	.33	.63	.86	.0079	.0147	.1189	.0072	.0139	1.94	
38	82:53	3.02	1.51	1.51	.21	.26	.56	.44	.93	.0053	.0229	.1715	.0050	.0154	2.61	
39	84:38	2.88	1.21	1.67	.12	.19	.46	.30	.83	.0032	.0222	.1485	.0031	.0131	2.53	
40	87:16	2.86	1.33	1.46	.15	.14	.43	.34	.92	.0041	.0161	.1427	.0038	.0151	2.42	
41	89:54	2.68	1.59	1.09	.19	.17	.64	.41	.96	.0049	.0202	.1879	.0047	.0160	2.08	
42	91:10	2.69	1.24	1.45	.14	.13	.43	.32	.86	.0037	.0155	.1118	.0036	.0137	2.28	
43	93:25	2.49	1.33	1.16	.14	.13	.61	.39		.0038	.0150	.1813	.0044		1.97	
44	1:48	2.75	1.47	1.28	.14	.11	.61	.38	.72	.0038	.0124	.1827	.0043	.0151	2.25	POST LUNAR MANEUVE METER TIME RESET TOO
45	62:41	1.14	1.14	0	.04	.10	.15	.77	.54	.0044	.0118	.1423	.0068	.0079	0	ENGINES ON
46	65:55	3.21	3.0	.22	.33	.42	.73	1.12	1.58	.0083	.0486	.2090	.0152	.0299	2.31	[illegible]
47	69:23	3.35	3.29	.52	.36	.46	.79	1.11	1.79	.0070	.0536	.2226	.0151	.0345	2.04	
48	71:08	3.27	3.24	.03	.40	.40	.73	1.01	1.83	.0079	.0456	.2094	.0150	.0356	1.92	
49	72:52	3.31	3.24	.07	.36	.65	.76	1.14	1.73	.0078	.0453	.2145	.0156	.0336	2.46	
50	74:37	3.10	2.68	.42	.32	.27	.65	1.05	1.42	.0080	.0313	.1917	.0139	.0263	2.22	

NASA-Langley Form 10 (AUG 1969)

TEST DATE : 1/31/85 (DAY 2)

VESSEL: SEAHAWK

TABLE 2
NASA RIDE QUALITY
METER MEASUREMENTS

RIDE CONDITION	METER TIME	DISCOMFORT INDICES									WEIGHTED RMS ACCELERATION LEVEL							
		DTOT	DVIB	DNOISE	DLONG	DPITCH	DROLL	DLAT	DVERT		GLONG	GPITCH	GROLL	GLAT	GVERT		DIN	COMMENT
51	76:21	3.06	2.68	.38	.29	.28	.64	.97	1.47		.0072	.0323	.1881	.0124	.0273		2.04	
52	78:06	3.17	2.95	2.23	.72	.33	.31	.63	.11		.0092	.0360	.1868	.0130	.0304		2.30	
53	80:12	2.80	1.95	.85	.14	.12	.63	.79	1.03		.0038	.0125	.1872	.0090	.0177		2.07	
54	83:17	3.23	1.98	1.25	.15	.13	.68	.64	1.12		.0040	.0161	.1976	.0074	.0177		2.74	
55	85:04	2.71	1.71	1.00	.17	.15	.65	.54	.99		.0045	.0170	.1906	.0062	.0167		2.05	
56	89:25	2.71	1.68	1.03	.22	.19	.61	.56	.97		.0057	.0224	.1823	.0063	.0163		2.08	
57	91:10	2.96	2.09	.87	.22	.20	.86	.68	1.07		.0057	.0233	.2373	.0077	.0184		2.25	
58	93:47	2.97	1.88	1.09	.20	.17	.73	.58	1.05		.0057	.0218	.2075	.0066	.0180		2.36	
59	96:24	3.05	2.34	.71	.10	.11	.54	.80	1.38		.0028	.0125	.1666	.0092	.0254		2.30	
60	99:53	2.91	1.82	1.09	.20	.17	.77	.52	.97		.0052	.0219	.2183	.0057	.0168		2.42	
61	10:31	2.75	1.41	1.35	.17	.15	.50	.53	.84		.0044	.0177	.1581	.0060	.0135		2.27	
62	10:00	2.65	1.61	1.05	.19	.17	.67	.41	.75		.0019	.0200	.1954	.0047	.0157		2.03	
63	10:07	2.87	1.76	1.11	.14	.81	.75	.51	.84		.0038	.0941	.2140	.0058	.0133		2.26	
64	00:00	2.67	1.15	1.53	.11	0	.14	.51	.34		.0030	.0214	.1589	.0037	.0110		2.29	METER TIME RESET TO 0
65	3:30	2.53	1.36	1.22	.13	.22	.33	.43	.90		.0034	.0257	.1194	.0047	.0117		2.00	
66	6:07	2.89	1.26	1.63	.16	.16	.52	.29	.83		.0042	.0181	.1617	.0032	.0132		2.60	
67	9:37	2.48	1.29	1.18	.10	.12	.61	.29	.80		.0028	.0137	.1812	.0032	.0125		1.95	
68	12:14	2.46	1.38	1.08	.14	.14	.70	.27	.80		.0038	.0161	.2008	.0031	.0125		1.88	
69	15:44	2.42	1.19	1.23	.11	.25	.60	.23	.74		.0030	.0386	.1804	.0026	.0111		1.93	

NASA-Langley Form 10 (AUG 1969)

TEST DATE : 1/30/85 (DAY 1) TABLE 3

NASA RIDE QUALITY METER MEASUREMENTS

VESSEL : SEAHAWK

Ride Condition / Meter Time	63 dBA	63 DN63	125 dBA	125 DN125	250 dBA	250 DN250	500 dBA	500 DN500	1000 dBA	1000 DN1K	2000 dBA	2000 DN2K			COMMENTS
1 19:11															Noise Turned off
2 20:33															
3 21:25															
4 22:17	68.19	.84	72.17	.90	73.43	.81	73.43	.66	73.60	.71	64.94	.60			Noise on
5 23:09	65.92	.51	72.97	.90	71.91	.66	73.19	.67	72.14	.64	67.30	.71			
6 24:01	66.99	.61	74.56	1.07	73.14	.81	73.82	.67	72.66	.64	66.82	.60			
7 25:46	68.98	.84	73.93	.97	74.04	.89	74.56	.93	72.78	.64	67.25	.71			
8 36:38	65.78	.51	73.14	.94	72.40	.73	73.14	.67	72.10	.64	67.06	.71			
9 27:30	67.96	.73	71.59	.81	71.95	.66	73.37	.67	72.53	.64	67.30	.71			
10 28:22	67.53	.73	73.14	.77	72.40	.73	72.96	.60	72.27	.64	70.86	1.08			
11 29:14	00.00	.00	74.2[illegible]	1.01	71.87	.66	72.78	.66	73.26	.71	68.38	.83			
12 30:06	00.00	.00	72.66	.90	73.02	.81	73.37	.67	72.61	.64	68.18	.83			
13 31:51	67.3[illegible]	.77	76.36	1.30	72.40	.73	72.66	.60	74.35	.78	67.30	.71			
14 33:35	65.78	.51	74.04	1.07	72.78	.73	77.44	.95	72.66	.64	68.57	.83			
15 35:19	00.00	.00	69.71	.63	69.16	.52	[illegible]	[illegible]	67.96	.34	68.59	.83			
16 37:04	[illegible]	[illegible]	67.66	.48	68.38	.45	73.76	.60	76.68	.93	00.00	.00			
17 38:41	00.00	[illegible]	66.57	.40	71.16	.66	71.85	.73	65.78	.24	00.00	.00			
18 48:43	[illegible]	.00	65.64	[illegible]	66.57	.33	68.49	.37	65.64	.24	00.00	.00			
19 50:28	00.00	.00	66.45	.40	66.10	.22	[illegible]	[illegible]	66.05	.29	00.00	.00			
20 54:11	00.0	.00	66.15	.40	66.76	.33	67.64	[illegible]	67.53	.34	00.00	.00			
[illegible] 55:46	00.00	[illegible]	[illegible]	[illegible]	65.64	.27	[illegible]	[illegible]	66.19	.29	00.00	.00			
[illegible] 57:32	00.00	.00	65.92	[illegible]	00.00	00.00	[illegible]	.27	65.21	.24	00.00	.00			
[illegible] 59:17	[illegible]	.00	00.00	[illegible]	[illegible]	.27	[illegible]	.27	[illegible]	.00	00.00	.00			
[illegible] 61:02	00.00	.00	65.61	[illegible]	00.00	[illegible]	[illegible]	[illegible]	65.06	.24	00.00	.00			
[illegible] 62:48	[illegible]	[illegible]	[illegible]	[illegible]	00.00	.00	[illegible]	[illegible]	65.64	.24	00.00	.00			

Note:

DNXX - Represents Noise Discomfort Due To Noise in The "XX" octave band.

dBA - A-weighted Noise Level.

TEST DATE 1/30/85

VESSEL : SEAHAWK

TABLE 3

NASA RIDE QUALITY

METER MEASUREMENTS

Ride Condition	Meter Time	63 dBA	DN63	125 dBA	DN125	250 dBA	DN250	500 dBA	DN500	1000 dBA	DN1K	2000 dBA	DN2K			COMMENTS
		Octave Frequency, Hz														
26	65:42	0000	00	66.19	.46	0000	0000	69.76	.42	0000	00	0000	00			
27	68:20	0000	00	65.64	.33	65.06	.27	68.88	.27	0000	00	0000	00			
28	71:51	0000	00	66.19	.46	65.64	.27	69.35	.42	70.62	.51	65.64	.50			
29	75:22	0000	00	0000	00	65.56	.29	67.64	.32	65.64	.24	0000	00			
30	78:54	0000	00	0000	00	66.32	.33	68.07	.27	0000	00	0000	00			
31	82:25	0000	00	65.98	.33	65.64	.27	67.86	.32	65.06	.24	0000	00			
32	85:57	66.22	.61	74.40	1.04	70.46	.59	70.77	.48	72.24	.64	0000	00			
33	89:29	67.55	.47	73.08	.97	72.34	.73	72.34	.60	73.24	.71	67.41	.71			
34	93:01	68.48	.84	77.03	1.41	71.59	.66	74.20	.73	74.20	.78	69.26	.95			
35	96:32	67.86	.73	76.46	1.30	70.93	.59	73.32	.67	72.16	.64	66.91	.60			
36	100:04	68.81	.84	79.76	1.64	74.20	.89	73.74	.67	73.58	.71	67.41	.71			
37	103:37	66.29	.61	75.04	1.01	73.77	.81	73.32	.67	72.17	.64	67.12	.71			
38	107:08	0000	00	0000	00	0000	00	69.26	.42	65.06	.24	0000	00			
39	111:10	0000	00	0000	00	65.64	.27	69.80	.42	65.56	.24	0000	00			
40	115:13	0000	00	0000	00	66.21	.34	69.80	.42	65.06	.24	0000	00			
41	118:44	0000	00	65.26	.33	65.06	.27	62.18	.37	65.36	.24	0000	00			
42	122:17	0000	00	65.21	.33	0000	00	70.14	.48	0000	00	0000	00			
43	126:04	[illegible]	00	0000	00	0000	00	0000	00	0000	00	0000	00			
44	127:35	0000	00	0000	00	0000	00	0000	00	0000	00	0000	00			

TEST DATE : 1/30/85

VESSEL : SEAHAWK

TABLE 3

NASA RIDE QUALITY

METER MEASUREMENTS

TIME / CONDITION / METER		OCTAVE FREQUENCY, HZ. 63		125		250		500		1000		2000		COMMENTS
		dBA	DN63	dBA	DN125	dBA	DN250	dBA	DN500	dBA	DN1K	dBA	DN2K	
45	52:50	0000	00	67.96	.42	0000	00	68.98	.37	67.96	.34	0000	00	
46	55:28	65.36	.51	69.53	.42	65.21	.27	69.07	.37	68.28	.39	0000	00	
47	[illegible]	0000	00	72.84	.90	66.45	.33	69.72	.37	67.95	0000	0000	00	
48	[illegible]	[illegible]	.84	[illegible]	.72	66.57	.33	69.18	.37	67.86	.24	0000	00	
49	[illegible]	66.57	.61	[illegible]	.81	66.90	.33	67.16	.42	69.44	.45	0000	00	
50	[illegible]	0000	00	72.29	.72	67.64	.34	69.07	.42	67.96	.45	0000	000	
51	[illegible]	66.19	.61	[illegible]	.22	68.38	.37	69.07	.39	0000	00	0000	00	
52	[illegible]	65.92	.51	71.73	.81	67.41	.31	68.18	.39	67.26	.45	0000	0000	
53	6:11	68.28	.84	75.23	1.19	67.53	.39	72.78	.37	68.98	.39	68.78	.37	
54	[illegible]	67.86	.73	72.97	.90	67.64	.31	69.26	.42	69.71	.45	65.06	.50	
55	[illegible]	69.06	.97	[illegible]	.90	[illegible]	.52	[illegible]	.42	67.62	.45	0000	00	
56	[illegible]	69.62	.97	72.90	.90	68.68	.45	69.44	.42	69.62	.45	0000	00	
57	[illegible]	69.53	.97	74.91	1.09	72.07	.73	72.08	.67	73.55	.71	68.07	.83	
58	[illegible]	67.53	.73	74.14	1.09	71.38	.66	73.34	.67	72.84	.64	67.18	.71	
59	[illegible]	[illegible]	.84	74.71	1.01	70.38	.59	72.40	.60	72.84	.61	[illegible]	[illegible]	
60	[illegible]	[illegible]	[illegible]	75.04	1.19	71.31	.66	73	.60	72.90	.64	67.18	.71	
61	38:52	69.44	.97	75.23	1.19	70.22	.59	72.43	.67	72.59	.64	68.18	.83	
62	[illegible]	71.87	1.22	75.96	1.19	[illegible]	.66	72.34	.66	72.34	.64	67.18	.71	
63	[illegible]	68.78	.84	72.16	1.17	72.47	.73	73.60	.67	73.14	.71	66.57	.60	
64	[illegible]	61.70	.97	73.88	.99	72.21	.73	72.46	.67	72.18	.64	66.94	.60	
65	56:31	67.41	.87	72.37	.97	72.07	.73	70.84	.66	72.27	.71	66.76	.60	

TEST DATE : 11/30/85

VESSEL : SEAHAWK

TABLE 3

NASA RIDE QUALITY

METER MEASUREMENTS

RIDE CONDITION / METER TIME	OCTAVE FREQUENCY, HZ 63		125		250		500		1000		2000		COMMENTS
	dBA	DN63	dBA	DN125	dBA	DN250	dBA	DN500	dBA	DN1K	dBA	DN2K	
66 60:57	69.53	.97	76.40	1.30	70.78	.59	72.30	.67	72.47	.64	66.70	.60	
67 65:.2	69.80	.97	75.75	1.19	71.80	.66	73.66	.69	72.01	.64	66.45	.61	
68 69:47	68.38	.84	75.01	1.17	71.45	.66	71.00	.73	73.00	.71	66.15	.60	
69 74:13	67.64	.73	76.01	1.53	72.66	.73	73.6[illegible]	.67	73.20	.71	66.82	.60	
70 78:37	70.14	1.10	72.96	.90	73.66	.81	72.96	.60	74.23	.78	66.57	.60	
71 81:16	68.78	.84	76.07	1.30	71.66	.66	71.73	.54	72.59	.64	69.21	.50	
7													

TEST DATE : 1/31/85 (DA13)

VESSEL : SEAHAWK

TABLE 4
NASA RIDE QUALITY METER MEASUREMENTS

Page 1 of 3

RIDE CONDITION / METER TIME		OCTAVE FREQUENCY, HZ 63		125		250		500		1000		2000		COMMENTS
		dBA	DN63	dBA	DN125	dBA	DN250	dBA	DN500	dBA	DN1K	dBA	DN2K	
1	1:35													
2	39:09													
3	41:27													
4	68:39													
5	70:56	0000	.00	0000	.00	0000	.00	0000	.00	0000	.00	0000	.00	Note:
6	75:21	0000	.00	0000	.00	0000	.00	0000	.00	0000	.00	0000	.00	
7	91:27	68.07	.84	75.77	1.19	72.07	.73	73.14	.67	73.32	.71	67.41	.71	DNXX - Represents noise discomfort due to noise in the "XX" octave band
8	94:11	66.94	.61	77.47	1.41	71.52	.66	72.21	.60	71.23	.58	66.70	.60	
9	98:49	62.49	.84	72.82	.99	70.62	.59	72.34	.66	71.60	.58	66.70	.60	
10	99:40	64.64	.73	75.22	1.19	70.62	.59	72.84	.60	75.32	.71	66.19	.60	
11	1:45	71.36	1.23	72.82	1.41	69.80	.52	72.47	.60	72.14	.71	67.16	.71	
12	5:15	67.11	.73	76.11	1.36	70.20	.59	72.59	.60	73.77	.60	68.69	.83	
13	7:38	67.86	.73	72.84	.90	72.34	.73	71.53	.54	74.66	.78	68.68	.83	dBA - A-weighted noise level
14	14:54	66.76	.61	71.87	.81	71.52	.66	71.66	.54	72.16	.64	66.82	.60	
15	20:18	66.70	.61	76.48	1.30	69.07	.52	70.62	.48	67.86	.34	0000	.00	
16	21:56	0000	.00	0000	.00	0000	.00	0000	.00	0000	.00	0000	.00	
17	28:04	0000	.00	0000	.00	0000	.00	0000	.00	0000	.00	0000	.00	
18	67:55	66.94	.61	76.48	1.70	74.60	.89	72.34	.60	74.46	.78	68.28	.83	
19	73:10	69.88	.84	76.46	1.36	72.84	.73	72.07	.60	74.51	.78	67.41	.71	
20	80:12	67.30	.73	77.04	1.64	73.32	.81	71.86	.54	73.08	.71	69.62	.95	
21	93:23	67.49	.74	74.61	1.07	62.17	.96	73.32	.67	72.54	.64	66.82	.66	
22	3:30	67.46	.73	76.60	1.20	70.93	.59	73.08	.67	72.10	.64	62.12	.71	
23	15:04	65.98	.61	74.30	1.09	68.98	.45	69.94	.42	69.99	.45	69.80	.95	
24	20:26	67.62	.77	72.84	.90	74.61	.84	72.34	.60	72.07	.64	66.70	.60	
25	25:42	67.41	.73	70.96	1.16	71.16	.66	73.20	.67	72.07	.64	66.82	.60	

NASA Langley Form 10 (AUG 1969)

TEST DATE : 11/1/85 (cont) TABLE 4. Page 2 of 3

VESSEL : SEAHAWK

NASA RIDE QUALITY
METER MEASUREMENTS
OCTAVE FREQUENCY, HZ

RIDE CONDITION	METER TIME	63		125		250		500		1000		2000		Comments
		dBA	DN63	dBA	DN125	dBA	DN250	dBA	DN500	dBA	DN1K	dBA	DN2K	
26	30:58	69.26	.97	73.55	.99	72.78	.73	72.77	.67	72.07	.64	67.30	.71	
27	36:14	67.75	.73	77.40	1.41	73.77	.81	73.32	.67	72.84	.64	66.82	.66	
28	43:17	68.17	.84	73.77	.99	71.23	.66	72.66	.60	72.07	.64	66.32	.60	
29	48:33	70.78	1.10	75.37	1.19	73.32	.81	72.51	.66	71.80	.58	68.57	.83	
30	52:58	68.49	.84	78.42	1.53	75.73	.98	73.08	.67	71.80	.58	67.64	.71	
31	56:27	68.88	.84	72.84	.96	69.26	.52	73.37	.67	72.96	.64	65.78	.50	
32	61:36	68.07	.84	77.16	1.64	75.96	.98	73.37	.67	72.07	.64	65.78	.50	
33	65:18	67.19	.73	78.80	1.53	72.10	.73	72.84	.60	73.55	.71	66.70	.60	
34	67:56	69.35	.97	75.55	1.17	73.32	.81	73.43	.66	73.43	.71	69.26	.95	
35	72:20	65.61	.51	74.40	1.09	73.08	.81	73.26	.67	72.59	.64	68.28	.83	
36	75:51	69.35	.97	74.80	1.07	71.08	.66	72.84	.66	73.08	.71	66.19	.60	
37	81:07	69.26	.97	72.07	.90	68.59	.45	72.84	.60	71.94	.58	67.64	.71	
38	82:53	67.41	.73	78.80	1.53	73.55	.81	72.84	.60	72.59	.64	68.49	.84	
39	84:38	69.35	.97	72.55	1.53	71.30	.59	72.46	.60	71.23	.58	66.82	.60	
40	87:16	71.23	1.23	75.46	1.19	73.37	.81	73.32	.67	71.52	.58	67.41	.71	
41	89:54	68.68	.84	74.30	1.07	71.80	.66	72.96	.60	71.94	.58	66.94	.60	
42	91:40	69.97	.99	75.23	1.17	73.60	.81	73.02	.67	71.52	.58	66.82	.60	
43	93:25	68.44	.84	72.31	.90	71.80	.66	73.32	.67	71.66	.58	68.07	.83	
44	1:40	69.80	.97	75.73	1.19	71.23	.66	72.84	.60	71.80	.58	67.18	.71	
45	62:41	0000	.00	0000	.00	0000	.00	0000	.00	0000	.00	0000	.00	
46	65:55	71.52	1.23	73.02	.99	71.38	.66	73.66	.67	71.80	.58	67.16	.71	
47	69:23	69.26	.97	73.17	.71	68.49	.45	71.66	.54	73.88	.71	68.28	.83	
48	71:48	69.35	.97	70.20	.92	69.44	.52	72.24	.60	72.72	.64	67.01	.71	
49	72:52	69.88	.97	72.24	.90	70.38	.54	73.93	.62	71.21	.58	72.92	1.35	
50	74:37	70.37	1.10	73.23	.97	71.80	.66	72.01	.60	71.93	.58	66.64	.71	

NASA Langley Form 10 (AUG 1969)

TEST DATE : 1/31/85 (DAY 2)

VESSEL : SEAHAWK

TABLE 4

NASA RIDE QUALITY METER MEASUREMENTS

RIDE CONDITION / METER TIME		OCTAVE FREQUENCY, HZ: 63		125		250		500		1000		2000		Comments
		dBA	DN63	dBA	DN125	dBA	DN250	dBA	DN500	dBA	DN1K	dBA	DN2K	
51	76:21	68.28	.84	73.32	.97	70.79	.59	73.97	.67	71.59	.58	66.68	.83	
52	78:06	71.08	1.23	72.66	.90	70.35	.59	73.91	.67	71.31	.58	68.49	.83	
53	80:42	69.35	.97	73.71	.99	72.27	.73	72.43	.67	70.86	.51	67.06	.71	
54	83:19	68.49	.84	79.57	1.64	71.23	.66	75.14	.60	72.01	.64	67.86	.71	
55	85:04	65.36	.51	74.46	1.09	71.16	.66	74.83	.73	71.31	.58	67.18	.71	
56	89:25	69.53	.97	73.47	.94	72.07	.73	74.51	.73	71.87	.58	66.70	.60	
57	91:10	68.78	.84	75.82	1.19	71.31	.66	74.35	.73	71.38	.58	67.64	.71	
58	93:47	67.18	.73	71.07	1.41	70.46	.59	74.71	.73	70.78	.51	66.94	.60	
59	96:24	70.22	1.10	75.00	1.01	72.01	.73	73.49	.67	71.16	.58	69.97	.95	
60	99:53	68.97	.84	74.75	1.09	72.01	.73	75.00	.73	72.21	.64	71.23	1.21	
61	10:31	66.32	.61	76.32	1.30	72.21	.73	73.[illegible]	.67	76.62	.51	67.18	.71	
62	10:00	67.29	.73	73.88	.99	73.08	.81	74.56	.73	71.66	.58	66.70	.60	
63	10:07	66.05	.61	76.80	1.30	72.07	.73	73.60	.67	71.01	.58	66.70	.60	
64	00:00	68.59	.84	76.64	1.30	71.66	.66	74.25	.73	69.71	.45	66.32	.60	
65	3:30	66.62	.61	71.80	1.09	72.53	.73	74.35	.73	69.97	.45	65.78	.50	
66	6:07	67.76	.73	75.42	1.19	73.37	.81	75.90	.80	72.47	.64	72.27	1.35	
67	9:37	68.98	.84	73.66	.97	72.46	.73	72.53	.60	70.54	.51	65.64	.50	
68	12:14	68.51	.84	73.08	.97	68.47	.45	72.34	.66	69.80	.45	66.19	.60	
69	15:44	66.32	.61	73.49	.99	72.96	.73	72.59	.60	71.94	.58	66.57	.60	

NASA Langley Form 10 (AUG 1969)